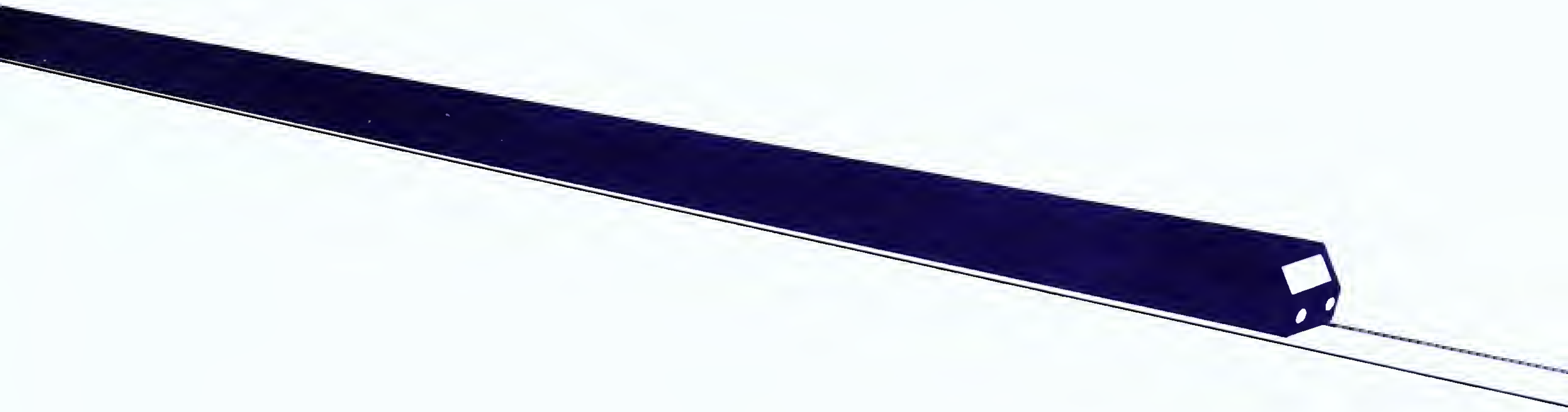
PENNSYLVANIA HIGH SPEED RAIL FEASIBILITY STUDY

PRELIMINARY REPORT
Phase 1

February 1985



for the

PENNSYLVANIA
HIGH SPEED INTERCITY
RAIL PASSENGER COMMISSION

Parsons Brinckerhoff / Gannett Fleming

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ACKNOWLEDGMENTS

Key members of the study team are listed below. The team included other members of the organizations shown whose efforts are sincerely appreciated. In addition, the study team would like to acknowledge the significant contributions to the study made by the following individuals or organizations:

- The Members of the Pennsylvania High Speed Intercity Rail Passenger Commission, and the Commission's oversight consultant, Executive Director and staff (see Chapter 1) whose valuable comments we believe to be reflected in this preliminary report.
- French National Railways, Sofrerail, and Japanese National Railways for operating experience and financial data on their high-speed services.
- Bombardier, Inc., The Budd Company and The TGV Company for information on candidate vehicles.

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The preparation of this report, has been financed in part through a grant from the U.S. Department of Transportation, Federal Railroad Administration to the Pennsylvania High Speed Intercity Rail Passenger Commission.

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CHAPTER 1
BACKGROUND AND INTRODUCTION

As Pennsylvania occupies a unique position in U.S. railroad history, so today is the United States unique among the highly-developed nations of the world. While passenger trains serve a significant portion of the intercity travel market in these countries, in the United States less than 1 percent of intercity trips were completed by rail in 1983. Yet, like much railroad technology, high-speed trains really began in America.

1.1 NATIONAL PERSPECTIVE

The first train to run at more than 100 mph was the New York Central & Hudson River's 4-4-0 steam locomotive No. 999, which hit 112 mph near Batavia, N.Y., in 1893. Only a dozen years later, on June 12, 1905, a Pennsylvania Railroad special train, pulled by E2-class coal-fired steam locomotive No. 7002, reached 127.1 mph near Elida, Ohio.

The General Motors diesel Aerotrain operated in regular passenger service between New York and Pittsburgh for several months in 1956. Its low center of gravity allowed it to traverse the largely twisting and mountainous Pennsylvania Railroad mainline at speeds of well over 85 mph, reducing the travel time between Philadelphia and Pittsburgh to six hours. And in 1974, an experimental train at the Transportation Test Center in Colorado sped down the track at 256 mph.

On May 26, 1934, the Burlington's diesel-powered, stainless-steel Pioneer Zephyr made its historic "dawn to dusk" run from Denver to Chicago in 13 hours. (Today, Amtrak's California Zephyr takes more than four hours longer to cover the same run.) This first "streamliner" was hailed then as the beginning of a new era, but it proved to be a short era indeed, because in the 1950s, rail passenger service was eclipsed by the airways and superhighways. The course of history seemed to have dictated termination of rail passenger service and the "romance of the rails" was not strong enough to overcome the historical imperative.

Except for an attempt by the U.S. Congress and President Lyndon Johnson to create "fast trains" in the Northeast Corridor via the High Speed Ground Transportation Act of 1965, the development of high-speed trains for passengers shifted to other countries, notably Japan, France, West Germany, Great Britain and Canada. As Interstate highway after Interstate highway was opened and as the Boeing 727 jetliner replaced the Pullman car as a symbol of long-distance travel, America's great steel-rail network fell out of the national consciousness and became almost wholly the domain of slow, heavy freight trains.

The single greatest exception to this trend was the Northeast Corridor, which attracted the attention of the federal government. The government's many years of attention to the Northeast Corridor, coupled with an investment of $2.19 billion, has resulted in improved service and increased ridership. Yet the Corridor trains hit top speeds of only 120 mph and average only 80 mph, better than the highways but not in the same league as European and Japanese high-speed railroads.

In 1964, Japan began running the famed Bullet Train at speeds of 125 mph. Although the Japanese National Railways continues to lose money nationally, the original Bullet Train (the Shinkansen) has made billions of dollars of profit since its 18th month of operation.[1,*] It is also considered the safest form of transportation in the world. More than 2 billion passengers have ridden it to date, with no injuries or fatal accidents. In France, the TGV (Tres Grande Vitesse, or very high speed) train system since 1981 has been transporting passengers between Paris and Lyon (260 miles) in two hours.

U.S. Senator Robert Taft of Ohio in 1972 called for a network of high-speed trains in his home state, to be built and operated independently of the federal government. His plan resulted in a study by the Ohio General Assembly's Legislative Research Service (LRS).[2] In 1975, an Ohio legislator named Arthur Wilkowski, who was armed with the LRS study, disenchanted with Amtrak's Northeast Corridor efforts, inspired by the Japanese and European ideas, and energized by the OPEC oil embargo, began the current movement to establish state-based and multi-state-based high-speed trains in America. He introduced legislation to create the Ohio Rail Transportation Authority, which was charged with developing a plan for high-speed rail in the Buckeye State.[3] This led to the formation of the five-state High-Speed Rail Compact (Pennsylvania, Ohio, Michigan, Indiana and Illinois). State Rep. Richard A. Geist of Pennsylvania became the compact's first chairman in May 1981.[4]

Other states, including Pennsylvania, New York, California, Texas, Florida and Nevada soon followed with plans and studies for high-speed trains in their corridors.

1.2 PENNSYLVANIA PERSPECTIVE

Pennsylvania has always been in the vanguard in the development of transportation, including canals, railroads and the world's first limited-access superhighway, the Pennsylvania Turnpike, which is a financial success as well as an efficient transportation facility. The Turnpike regularly pays its bondholders, maintains facilities in excellent condition, pays for state police and other services, and has built extensions, widened parts of the roadway and eliminated tunnels -- all from its own revenue. No state tax funds have ever been appropriated to the Turnpike.[5]

With this history, Pennsylvania leaders in the mid-1960s began considering high-speed rail passenger service. In February 1967, the state Commerce Department received a study performed by Westinghouse Air Brake Co. (WABCO) of Pittsburgh on 150-mph trains for the "Keystone Corridor" between Philadelphia and the Ohio border. West of Harrisburg, this line was to have roughly paralleled the Turnpike; east of Harrisburg, it would have used the Pennsylvania Railroad main line right of way.[6] While the plan for cross-state improvements never materialized, some of the study's recommendations were adopted in a proposal to enhance the Pennsy's Philadelphia-Harrisburg service.

In conjunction with the federal high-speed demonstration project that was then getting under way on the Northeast Corridor, the state and the Pennsy agreed to jointly fund a purchase of 11 electrically powered Budd Co. "Capitaliner" coaches that were identical to the 50 Budd Metroliners that were being built for Northeast Corridor service. In the interim, service frequency on the 104-mile route was increased by using electrified commuter cars from the Southeastern Pennsylvania Transportation Authority (SEPTA).

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* Throughout this report, numbered footnotes refer to references contained at the end of each chapter.

The state allocated $2 million as its share of the $4.5 million capital cost for the "Capitaliners;" the railroad's contribution was to have been $2.5 million. However, in the meantime the Pennsy had merged with the New York Central Railroad to become Penn Central. Complex forces in the market, in the political arena and among the personalities in leadership combined to render the merger unsuccessful from both operational and economic standpoints, and PC declared bankruptcy on June 21, 1970. This derailed the plan to jointly fund high-speed equipment for Pennsylvania, and the 11 Capitaliners went into the Northeast Corridor New York-Washington Metroliner pool.

SEPTA's cars shuttled back and forth between Philadelphia and the state's capital city for years, even after Amtrak assumed responsibility for the service in May 1971 and acquired the Philadelphia-Harrisburg right-of-way in 1976 as part of the formation of Conrail. Amtrak later leased commuter cars from the state of New Jersey for the service. Later, when new locomotive-hauled trains began running in the Northeast Corridor as part of the Northeast Corridor Improvement Project, Amtrak reassigned some of its surplus Corridor trains to the Harrisburg line, allowing the return of the New Jersey equipment. Ironically, the now-surplus trains reassigned to the Harrisburg line were the original Metroliners, including "Capitaliners," all of which Amtrak had acquired along the way.[7]

Amtrak has spent more than $30 million on welded rail, bridges, signals, catenary, fence and other right-of-way improvements on the Harrisburg line. This has opened some stretches to speeds as high as 90 mph -- faster than authorized even in the Pennsy's best days.

While the speeds and frequency of service found on the Harrisburg line are enviable to rail riders who live outside the Northeast Corridor, the service neither fits the contemporary global definition of high-speed rail nor serves a statewide constituency. Indeed, cross-state service had withered from more than a dozen trains each way daily as late as the mid-'50s to just three a day in 1971 after Amtrak took over.[8] The level dropped to an historic low -- one train a day each way (the Broadway Limited between New York and Chicago) in 1979 -- the smallest amount of service since 1854, when the Pennsy's through route over the Horseshoe Curve was opened. The next year, a daily state-subsidized Philadelphia-Pittsburgh Amtrak train began running, and while it has become successful from ridership and revenue standpoints, it still takes about seven hours to make the cross-state run.[9]

It was in this context, then, that the possibility of constructing a new Pennsylvania high-speed rail system emerged. In January 1981, Rep. Geist (soon to become chairman of the five-state Compact) and state Rep. Joseph Kolter of New Brighton sponsored bipartisan legislation to establish the Pennsylvania Intercity High Speed Rail Passenger Commission. The legislation attracted 141 co-sponsors out of 203 members of the Pennsylvania House. It was adopted unanimously and signed into law by Gov. Dick Thornburgh on Dec. 22, 1981.[10]

Relevant portions of the act follow:

> "The commission shall have the overall responsibility, power and duty to investigate, study and make recommendations concerning the need for and establishment and operation of a high speed intercity rail passenger system in the Commonwealth. The commission shall, without limiting its authority to study related subjects, address the following specific areas and issues:
>
> (1) The need and demand for high speed intercity rail service in the Commonwealth.
>
> (2) The level of high speed rail service required to meet the need for such service.
>
> (3) System, equipment, roadbed, right-of-way and other technical and technological options such as electrification.
>
> (4) Location and extent of the specific routes in the system.
>
> (5) Cost of implementing the system.
>
> (6) Economic impact of the system.
>
> (7) Financing, ownership and operating options for the system.
>
> (8) Impact and interaction of the system on existing rail freight operations and on existing or proposed rail passenger systems.
>
> (9) Present or proposed operation of similar systems in the United States and in other countries.
>
> (10) Issues and problems relating to local and commuter rail service including funding."

Named as legislative members of the commission were Representatives Geist, a Republican from Altoona, and Kolter, a Democrat, and state Senators Robert C. Jubelirer (R-Altoona) and James E. Ross (D-Beaver). Named as rail labor representative was Everett W. Croyle, the United Transportation Union's state legislative director. Richard C. Sullivan, a vice president of Conrail, which has more than 9,000 miles of track in Pennsylvania, was named industry representative. Don Bryan, a deputy secretary of the Pennsylvania Department of Transportation (PennDOT), was named representative of the executive branch. Robert A. Gleason Jr., a Johnstown insurance executive, and Robert A. Patterson, vice president and treasurer of Pennsylvania State University, were selected by Gov. Thornburgh to represent the public interest.

In January 1983, Rep. Kolter became a member of Congress and was succeeded on the commission by state Rep. Amos Hutchinson (D-Greensburg). In September 1984, Mr. Bryan was succeeded on the commission by Kant Rao, state deputy secretary of budget.

Following passage of the initial act, several other pieces of legislation and appropriations were required, resulting (over four years) in seven unanimous legislative votes in support of the commission, and one, in 1982, which was unanimous in the Senate and drew only three negative votes in the House.

This strong bipartisan support resulted in a unique situation early in 1984, when the commission's 1984-85 budget was passed unanimously and signed by the governor before the rest of the state budget was taken up by the legislature for consideration and debate.[11]

The commission began operations on Feb. 14, 1983, when Robert J. Casey of Pittsburgh assumed the duties of executive director. He issued a Request for Proposals on April 23, 1983, for a General Engineering Consultant initially to perform a feasibility study of alternative high-speed rail systems within the Pennsylvania Corridor. The joint venture team of Parsons Brinckerhoff/Gannett Fleming was selected at the commission meeting of June 28, 1983 and a contract was awarded to the joint venture on Aug. 16, 1983.

Subcontractors on the PB/GF team and their assignments include: Gibbs and Hill, Inc., a Dravo Corp. subsidiary, power systems; Sofrerail of Paris, France, technology requirements and maintenance; the law firm of Dechert Price & Rhoads of Philadelphia, legal and institutional issues; Ernst & Whinney of Washington, economic impact, investment and financing analysis; Prudential-Bache Securities, public and private financing options; and Westmoreland Engineering of Monessen, right-of-way and major structures support.

The commission additionally awarded a contract to STV Engineers, Inc., on May 16, 1984, to serve as an oversight consultant that would verify, reject or clarify the findings of Parsons Brinckerhoff/Gannett Fleming. Subcontractors include R.L. Banks & Associates of Washington; Daniel, Mann, Johnson & Mendenhall of New York; and Rackoff Engineers of Columbus, Ohio.

In the chapters that follow, the activities, results and findings of Phase 1 of the feasibility study are described in detail, together with an overview of the scope of the remaining phases.

References:

1 Testimony of Dr. Koji Takahashi, senior vice president, engineering, Japanese National Railways, before the Subcommittee on Transportation, Aviation and Materials, U.S. Congress, April 6, 1982.

2 Report on High Speed Rail Passenger Service, Ohio Legislative Research Service, 1973.

3 Section 4981, Ohio Revised Code.

4 Appropriate laws of Illinois, Indiana, Michigan, Ohio and Pennsylvania, and federal law H.R. 4308.

5 The Pennsylvania Turnpike, A Brief History, 1983.

6 Demand, Supply and Economic Impact of Transport in the Keystone Corridor, Westinghouse Air Brake Co., February, 1967.

7 Dan Cupper, "The Demotion of a Faded Speedster," Passenger Train Journal, January 1982, pp. 9-11.

8 Amtrak system timetable, May 1, 1971.

9 Amtrak system timetable, Oct. 28, 1984.

10 Act 1981-144, Laws of Pennsylvania.

11 House Bill 1832, signed into law May 1, 1984.

CHAPTER 2
PROJECT SCOPE AND METHODOLOGY

The Pennsylvania High Speed Rail Feasibility Study is divided into three program phases, spanning 37 months. The three phases represent a procedure for narrowing the range of options and increasing the level of detailed knowledge of the preferred alternative as the program proceeds.

The first phase amounts to a preliminary feasibility study of high-speed rail options, with a strong emphasis on transportation demand forecasting. It is anticipated that the Commission will select one option for further development in Phases 2 and 3.

Phase 2 consists of a more detailed, site-specific evaluation of the Commission's selected option. The cost estimate and technical infrastructure requirements developed in Phase 2 for the selected alternative will have a higher degree of accuracy than those employed in the Phase 1 study, since they will be based on more site-specific information obtained through site visits and other field investigation. In addition, Phase 2 will include transportation data surveys and market surveys intended to validate some of the transportation demand issues which, because of shortcomings in the available data, had to be treated in Phase 1 as assumptions.

In Phase 3, the chosen system will be shaped into an implementation plan. This involves the resolution of complex ownership and operations issues that affect the organizational structure of a high-speed rail enterprise, as well as its coordination with connecting and parallel carriers, particularly Southeastern Pennsylvania Transportation Authority (SEPTA), Amtrak and Conrail. In order to bring about a high-speed rail (HSR) system in Pennsylvania, specific enabling legislation will be required, as will be changes to existing federal and state legislation, to permit favorable tax treatment. These issues will affect whether an HSR system can be financially feasibile. Detailed financing plans will be developed in Phase 3 in concert with the proposed legislative program. Finally, the most detailed statement of the positive economic impact which HSR service would have on the Commonwealth will be prepared as a part of this phase.

In many respects, Phase 1 is a microcosm of the entire three-phase study. This is necessary because the "workability"[1] of an HSR enterprise, which is critically dependent upon the demand for the transportation services provided, cannot be determined in isolation. Because HSR systems vary widely in their ability to tap demand (that is, attract ridership through combinations of trip time, frequency, fare level and amenities), and because they vary equally widely in cost and in ability to generate revenue, it was necessary to examine all of the potential technologies. As a result, the Phase 1 study was expanded from a transportation demand analysis to an analysis of the relative feasibility of a range of transportation alternatives. The following section describes the Phase 1 methodology in general terms.

2.1 GENERAL PHASE 1 METHODOLOGY

The methodology consists of basic activities, which are the building blocks of the feasibility study, and are described in detail in Chapters 3 through 17.

- Technology Assessment: Candidate technologies from around the world are examined for consideration in the Pennsylvania corridor, as discussed in Chapter 3.

- Definition of Alternatives: Candidate technologies are grouped, as appropriate, into classes for preliminary analysis in Phase 1. These classes are matched with alignment types (existing, new, or hybrid/combination alignments) and suitable technical criteria, and become preliminary alternatives. These are described in Chapter 3.

- Alignment Studies: Rights-of-way, alignments, and configurations of track or guideway are then analyzed and candidates drawn. These alignments, when refined and checked, become the bases for trip time estimates. Alignment development is discussed in Chapter 4.

- Train Performance Estimates: Candidate high-speed vehicles are examined from operations around the world and matched with appropriate alternatives. The operational characteristics of these trains and constraints posed by specific alignments are then entered into a computer routine which calculates speed-time-distance performance and energy consumption. These considerations are discussed in Chapter 5.

- Operations Plan Concept: Concepts of how the proposed rail systems would be operated, together with the implied effects on the traveling public and related transportation modes are developed. This planning includes "service features" (e.g. train frequency, baggage and food service policies, on-board amenities, and passenger interaction with the system) as well as transportation, marketing, and maintenance functions. The development of the operations plan concept is discussed in Chapter 6.

- Infrastructure Requirements: The information developed up to this point is sufficient to identify the major physical components needed to provide HSR service called for by each alternative. Concept, design, and cost of these components are affected by overall transportation demand, and as a result this activity must be closely coordinated with the demand estimating process with a sequential procedure providing a balancing of infrastructure supply and transportation demand. The individual requirements in each area of technical specialization are discussed in Chapter 7 for each final alternative.

- Cost Estimates: Closely paralleling the development of the infrastructure requirements is the development of unit costs and quantities, which then are used to assemble integrated capital cost estimates for the final alternatives. In addition, operating and maintenance (O&M) cost estimates are prepared based on the operations plan concept. The approach to cost estimating and the resulting estimates are presented in Chapter 8.

- Transportation Demand Estimates: Data on existing transportation modes, existing trip patterns, existing transportation demand, population and income are assembled and analyzed. Computer models are constructed to attempt to duplicate existing trip generation and mode split, and these models are validated using existing data bases. After validation, the characteristics of the new mode (one of the high-speed systems) are added to the model and new trip generation and mode split runs are made. Future trends in population and income are also factored into the resulting ridership projections. Demand estimating methodology and resulting estimates of future demand are detailed in Chapter 9.

- Fares and Revenue Estimates: Investigations of the prevailing fare levels in the Pennsylvania rail corridor, other appropriate corridors, and other modes are made. These are used to help estimate demand and, following development of ridership forecasts, to calculate passenger revenues. Additional revenue sources are identified, as are corresponding additional costs, to arrive at net revenues. Development of these estimates is discussed in Chapter 10.

- Financial Projections and Financial Feasibility: Capital and operating costs are projected over time, as is revenue from ticket sales and other activities, through the construction, pre-operation and operating periods. An investment analysis is performed from both the public financing and private financing standpoints, to gauge the financial return of each alternative. Against the backdrop of relative rates of return and relative risks, the financial feasibility of each alternative is addressed. A conceptual financing package is suggested. Cash flows and investment analyses are discussed in Chapter 11 and financial feasibility is presented in Chapter 12.

- Other significant factors:

  - Institutional factors — those relating to the form of organization of the HSR enterprise, as well as its relationships with other carriers and government bodies—are discussed in Chapter 13.

  - Significant positive economic impacts are determined through the use of regional input-output modeling, as described in Chapter 14.

  - The environmental impact of remaining on the existing Amtrak/Conrail (former Pennsylvania Railroad) mainline right-of-way in contrast to assembling a new right-of-way is presented in Chapter 15.

  - Although foreign precedents cannot be considered directly applicable to potential projects in the United States, an examination of successful HSR projects abroad may be worthwhile. A discussion of the economic performance of HSR systems in France and Japan is presented in Chapter 16.

- Evaluation of Alternatives: The final alternatives are evaluated, with emphasis on financial viability, in Chapter 17.

References

1 "Workability" implies a broad interpretation of feasibility and embraces technical, economic, and political feasibility.

CHAPTER 3

HIGH SPEED RAIL TECHNOLOGIES AND DEVELOPMENT OF ALTERNATIVES

A review was undertaken of the most significant high-speed rail operations around the world. While their experiences cannot be directly "transplanted" to Pennsylvania, the basic characteristics (alignments, technology and vehicle choice, speeds) represent the state of the art. These operating services and development projects contain the elements from which the components best suited for application in Pennsylvania can be selected.

3.1 HSR TECHNOLOGY

As with all ground transportation systems, the right-of-way and route alignment selected for a Pennsylvania HSR system will determine its capabilities to a large extent. While different kinds of HSR trains perform differently over the same alignment, a more fundamental issue is that of the alignment itself: Is it Existing or New? Most existing rail alignments were constructed primarily for freight purposes, and so contain inherent limitations for high-speed passenger service. The Pittsburgh-to-Philadelphia Corridor, with 392 curves, or 1.1 curves per route-mile, is a severe case of a restrictive alignment for very-high-speed service.

Totally new alignments can be formed which are geometrically ideal for high-speed service, but at very substantial cost for right-of-way assembly and construction. Compromises between existing and new alignments are also possible. Worldwide, there are five basic combinations of alignment and technology for high-speed ground transportation. Some are in revenue service and others are purely experimental. They are:

ALIGNMENT	TECHNOLOGY
Existing	Conventional Rail
Existing	Improved Rail
Straightened Existing	Improved Rail
New	Advanced Rail
New	Levitated Vehicle (Maglev)

3.1.1 Alignment-Technology Combinations

- Existing Alignment — Conventional Rail: Passenger trains operate along with freights on the same right-of-way and the same tracks. Locomotive-hauled coaches are the usual train equipment. Curves, grades, highway and rail crossings at grade, older structures and other obstacles prevent continuous high-speed running, as does track condition. This type of operation is provided as standard service (as contrasted with premium service) around the world, as for example by Amtrak outside the Northeast Corridor.

- Existing Alignment — Improved Rail: Substantial investment in physical plant is involved here. Roadbed is rebuilt, signal and communication systems are upgraded, and bottlenecks such as junctions and yard approaches are reworked. Though sharing the basic right-of-way, high-speed passenger tracks are provided to high standards of geometry (although they may be shared with freight in some locations). Trains may be electrically powered or diesel-powered, but in either case a high ratio of horsepower per ton of weight is maintained. Electric propulsion has the edge in performance, but catenary structures must be provided for high-speed current collection over a wide range of temperatures and operating conditions. Trains can be either of multiple-unit type (as the original Metroliners) or locomotive-hauled (as Amfleet/AEM-7s). This type of service is typified by much British Rail service, French National Railways service, and Amtrak's Northeast Corridor service.

In locations where track curvature is fairly severe, this type of service may incorporate tilting-body trains, which squeeze additional performance out of the alignment by allowing trains to travel faster around curves without unacceptable levels of lateral force on the passenger (Italy's Pendolino, Canada's LRC, and the former U.S. TurboTrain among others).

- Straightened Existing -- Improved Rail: The best of both worlds is hoped for: the existing alignment serves the population centers directly, allowing passengers to walk to and from their destinations or take a short transit trip at stations. The most restrictive curves are eliminated or eased by realignment, generally requiring the acquisition of property. In the extreme case, much of the line may be new, retaining existing track only in and near cities, both to minimize acquisition cost and to serve the existing population centers best. The realignment case is typified by early plans for Northeast Corridor improvement (1976 -- not implemented), and the substantially-new case is exemplified by French National Railway's Paris-Lyon service using the TGV. All of the technology of Improved Rail as just described is used here and, in addition, dedicated passenger tracks are provided as a general rule (i.e., freight trains do not run on the passenger tracks except under emergency conditions).

- New Alignment -- Advanced Rail: New alignments are employed when less costly alternatives will not meet the performance requirements, where regional development mandates the route location, or where there is simply no existing line suitable for high-speed service. The new alignments permit sustained high-speed operation, allowing significant increases in average speeds and sharply reduced running times.

  The regional development imperative has dictated railroad expansion in the Soviet Union, where railroad electrification also serves as the primary power supply for homes and factories in the less-developed quarters. Japan's network of narrow-gauge lines was saturated with commuter traffic, necessitating a new alignment for high-speed service and eliminating the disruption and social cost of reconstruction. The Japanese National Railway's original Shinkansen, the New Tokaido Line (NTL), was built to be an ultra-straight railroad — fully one-third of its length is on structure or in tunnel—at necessarily high cost. The famed Japanese bullet trains are of multiple-unit type and are not radically different from Metroliners, both designed to operate at top speeds of 120 to 130 mph. As a comparison point, the NTL shortened the travel time from 6.5 hours to 3 hours 10 minutes between Tokyo and Osaka in 1964 (a 51 percent reduction in travel time); this serves to put in perspective the Commission's goal of reducing the 7-hour schedule from Pittsburgh to Philadelphia to 2.25 hours (a 68 percent reduction).

- New Alignment — Levitated System (Maglev): The possibility of superspeed trains (200-300 mph) has been actively researched in the United States and abroad in the last two decades. The U.S. government HSGT program[1] evaluated a number of advanced technologies and concluded that Maglev had the most potential, but abandoned the program because of funding constraints. Japan and West Germany have continued to develop this technology, but no commercial applications have been constructed.

  Maglev technology is incompatible with existing railroad plant, and needs a right-of-way of its own to take full advantage of its high-speed capabilities. This nearly complete freedom from existing rights-of-way is an advantage in designing a system without geometric constraints. Its weak points are the environmental impact of the requirement to serve existing population centers, the cost of the right-of-way required and the lack of commercial service experience.

3.1.2 Means of Achieving Improvement

Before proceeding with a more complete description of the alternatives, it is worthwhile to discuss means of achieving trip time improvement in general terms. The major categories of improvement considered and the rationale for their consideration are listed below:

Subsytem	Category of Improvement	Rationale
Track/ Alignment	Upgrading to higher FRA classification	May be a requirement for higher speed
	Raising superelevation up to 6 inches	An inexpensive way of obtaining higher speed curves if track use can be dedicated to passenger service
	"Designation" for primary use of passenger trains	May avoid the expense of constructing additional dedicated trackage
	Curve straightening	May avoid cost and impact of route realignment, with nearly the same improvement in speed capability
	Route Realignment	May be desirable in areas of high route circuity or extreme curvature
	New alignment	May be the only way to obtain the desired trip time
Equipment (Vehicles)	Increased power density (hp/ton)	May provide improved performance at a reasonable cost

Increased cant deficiency (tilt-body vehicles)	May provide significantly improved performance at a reasonable cost
Electrification	Though costly, may be the best way to provide the desired performance
Advanced technology (Maglev)	Though costly and presently unproven, it is the only way to provide 2.25-hour ground transportation between Philadelphia and Pittsburgh

All these categories have been explored in this study. While certain combinations of improvements may appear less attractive economically than others, all have been reviewed so that the analysis would be complete. The purpose of the Phase 1 study is to choose among the five basic alternatives. Details need not be decided until later, following the determination of which alternative looks most attractive for further study.

3.2 DEFINITION OF ALTERNATIVES

Two principles were followed in drawing up HSR proposals: First, the broadest possible range of alternatives was sought; and second, each alternative was intended to seek the best performance under certain limitations.

These are the five basic alternatives selected for detailed study:

- Alternative A is the Baseline or "do nothing" alternative. It represents today's service capabilities only, and is included as a reference point against which to measure improvements.

- Alternative B represents the best service that could be provided on the existing Amtrak/Conrail right-of-way without fully-dedicated passenger tracks.

- Alternative C represents the best service that could be provided on the existing Amtrak/Conrail right-of-way with limited curve and route realignments and with dedicated passenger tracks for the most part. Alternative C was studied with and without full (end-to-end) electrification to gauge the effects of this technically-desirable feature.

- Alternative D represents the best service that could be provided on a totally new right-of-way with advanced steel-wheel-on-steel-rail rolling stock and motive power. Alternative D was studied in two forms: a basic alignment serving the traditional population centers[2] in the Corridor, and an optional alignment that would add State College to the route.

- Alternative E represents the best service that could be provided on a totally-new right-of-way with magnetic levitation.

It should be noted that, as formulated above, these alternatives are not cost-constrained and are performance-oriented. Judgment has been used in the alternatives development process, however, in an effort to balance cost and ease of implementation against the degree of improvement. For example, Alternative C was examined with between one and 15 route realignments. The final Alternative C contains the five best realignment projects (best in terms of cost vs. trip time improvement). As another example, Alternatives D and E originally examined entirely new rights-of-way between Philadelphia and Pittsburgh. Because of the high cost and large environmental impact of developing new rights-of-way in the urbanized zones near Philadelphia and Pittsburgh, and the relatively small time savings associated with those new alignments in those areas, the final Alternatives D and E utilize existing rights-of-way in part.

It should also be noted that specific rail or Maglev vehicles are not selected as a part of the alternatives generation and analysis process. At this preliminary stage of the feasibility study, typical vehicles are employed to indicate the performance capabilities of each alternative. Additional sensitivity runs are performed to indicate the effect of changes in assumptions, including different vehicle consists. In Phase 2 of the feasibility study, appropriate vehicle candidates will be evaluated in more detail to determine which one or ones may represent an optimum choice for the selected alignment alternative.

In the development of alternatives, the study team took notice of the basic assumption stated in the RFP that "HSR...will not impose on (the) tracks or operations..." of Amtrak and Conrail. This statement clearly does not apply to Alternative A, which represents existing conditions. Alternative B, which utilizes existing track exclusively, is not compatible with this assumption. Alternatives C, D and E are intended to comply with the assumption and, while generally doing so, do not comply in the vicinity of some stations, as more fully described in subsequent chapters. Efforts to achieve full compliance will continue in Phase 2.

3.2.1 Features of Preliminary Alternatives

Table 3-1 provides a summary of system features under each alternative. The following text describes these features in detail:

- Alternative A -- Baseline

  Passenger train service would continue to operate as it does today. Diesel locomotive-hauled coaches are used in the present Amtrak service between Philadelphia and Pittsburgh. Curves, grades, highway grade crossings and rail crossovers and other obstacles prevent sustained high speed, as does track condition, signaling system limitations, and traffic mix. The maximum speed between Philadelphia and Harrisburg is 90 mph and between Harrisburg and Pittsburgh is 70 mph. It is assumed that improvement projects currently underway in the corridor by Amtrak and Conrail will continue; however, no additional passenger-related improvements are proposed.

  Over most of the route, track superelevation in curves, referred to as E_a (actual elevation) is constructed at less than the U.S. standard maximum of 6 inches because of the predominance of freight traffic. The permissable speed of passenger trains in curves is computed by a formula based on the

TABLE 3-1

SYSTEM FEATURES BY ALTERNATIVE

Item	Alternative					
	A	B	C	C-Electric	D	E
	Baseline	Limited Improved	Improved Existing	Improved Existing (Electrified)	HSR	Maglev
Alignment	Existing	Minor realignment within existing ROW	Base case: Existing route with 5 route realignments & 44 curve realignments		Existing Route: Philadelphia-Harrisburg and Greensburg-Pittsburgh New Route: Harrisburg-Greensburg	Existing Route: Philadelphia-Malvern New Route: Malvern-Pittsburgh
Track	Existing	Upgraded existing	Upgraded existing 2 tracks: Philadelphia-Harrisburg; 1.5 new tracks: Harrisburg-Pittsburgh (wood ties)		Entirely new double track (concrete tie)	New Guideway
Traffic Separation	Mixed	Mixed	Designated passenger tracks		Dedicated HSR	Dedicated
Maximum Effective Curve Elevation*	Up to 9"	Up to 9"	Up to 15" (6" E_a + 9" E_u)		Up to 10.5" (6" E_a + 4.5" E_u)	Up to 14.5" (12° bank angle + 3" E_u)
Maximum Grade	Existing	Existing	3 percent		3.5 percent	6 percent
Maximum Speed, mph	90 Philadelphia-Harrisburg; 70 Harrisburg-Pittsburgh	110 Philadelphia-Harrisburg; 90 Harrisburg-Pittsburgh	110 to 120		160 to 180	250
Grade Crossings	Existing	Existing with protection	Eliminated where feasible		100% eliminated	100% eliminated
Fencing	Existing (minimal)	Existing (minimal)	10% of ROW	10% of ROW & overhead bridges	100% At-grade ROW & overhead bridges	100% At-grade ROW & overhead bridges
Electrification	Existing: (Not used in Philadelphia-Pittsburgh service)	Not used	Not used	Upgraded: Philadelphia-Harrisburg; New: Harrisburg-Pittsburgh	Upgraded: Philadelphia-Harrisburg; New:Harrisburg-Pittsburgh	All new
Signals & Communications	Existing	Upgraded existing	Upgraded existing	Upgraded: Philadelphia-Harrisburg; New: Harrisburg-Pittsburgh	All new	All new
Stations	Existing	Rehabilitated existing	Rehabilitated existing and new (high-level platforms)		Rehabilitated existing and new (high-level platforms)	All new
Maintenance Facilities	Existing	Upgraded existing	All new	All new	All new	All new
Equipment Type	F40PH/Amfleet	Diesel trainset (tilt-body)	Diesel trainset (tilt-body or conventional)	Electric trainset (tilt-body or conventional)	High-speed electric train	TR-06 or MLU-001 type train

* Maximum Effective Curve Elevation is defined as the sum of track superelevation (actual elevation, E_a) and unbalanced elevation (E_u).

degree of curvature and the total elevation (E), which is the sum of actual elevation and unbalanced elevation ($E_a + E_u$). The combination of low existing curve elevation and high degree of curvature in major segments of the route is a factor significantly limiting trip time.

- Alternative B -- Limited Improved

  New diesel-powered, tilt-body trains would reduce trip times, without substantially raising the maximum speed, by raising the speed in curves. Tilt-body trains are able to traverse curves at speeds up to 20 to 30 mph faster than normal without imposing excessive lateral acceleration on passengers.

  Track and signal upgrading and minor track realignment would also be accomplished, but without requiring the purchase of any new right-of-way. Existing superelevation in curves would be maintained for freight operations. Passenger and freight trains would continue to share tracks, but the volume of freight traffic and speed differential would prevent any substantial increase in passenger-train frequency.

- Alternative C — Improved Existing

  Improved passenger service would operate on upgraded and new trackage generally within the existing right-of-way. The tightest curves would be realigned to shorten trip time, in many cases requiring the acquisition of additional property. New trackage for passenger trains would almost eliminate freight train interference. (Freights would not share passenger trackage, except in the vicinity of stations.) Diesel- and electric-powered tilt-body trains and new electrified trains of conventional design are considered as candidate equipment. Trip times would be improved substantially but would still be limited by conventional track speeds, route curvature and route length.

- Alternative D — High Speed Rail

  The HSR alternative considers a new alignment and advanced high-speed rail technology modeled after the French TGV Paris-Southeast service or Japanese Shinkansen (Bullet Train). Trains would be electrically powered and operated on new, dedicated trackage at maximum speeds of 160 to 180 mph, providing 3.25-hour trip times between Philadelphia and Pittsburgh.

  Existing right-of-way would be used between Philadelphia and Harrisburg and between Greensburg and Pittsburgh to minimize community impact in these areas. The route would be located on a new right-of-way between Harrisburg and Greensburg except in the vicinity of passenger stations.

  Grade crossings would be eliminated and the right-of-way fenced. Stations would be built or rebuilt to accommodate increased patronage.

- Alternative E -- Maglev

  This proposal involves a new, very-high-speed system modeled after the German or Japanese Maglev technology demonstrations. A new guideway would be built within the existing right-of-way between Philadelphia and Malvern and on a new right-of-way from there west to Pittsburgh—except in some short segments in the vicinity of passenger stations. Speeds up to 250 mph would be possible providing a trip time which approaches the 2.25-hour goal established by the Commission.

References

[1] See Reference 2, Chapter 1.

[2] A ground rule of the Request for Proposal was that the HSR route serve Lancaster, Harrisburg, Altoona, Johnstown and Greensburg in addition to the terminal cities of Pittsburgh and Philadelphia. HSR service at Paoli was also examined to draw on the large ridership base of the metropolitan Philadelphia area.

CHAPTER 4
ALIGNMENT ALTERNATIVES

Each route, other than the Baseline, has been plotted on 1:24,000 scale United States Geological Survey (USGS) topographic maps for the purpose of initial quantity takeoff and evaluation. These maps provide a preliminary site-specific plan of each route alternative. It should be noted that not all USGS maps are up to date. Later, aerial surveys and field checking can confirm conditions along the proposed routes.

Following is a more detailed description of each candidate alignment. Reduced scale maps, showing the proposed alignments, are provided in Figure 4-1.

4.1 ALTERNATIVE A

The 352-mile-long existing route is characterized by numerous curves, grade crossings, bridges, and two tunnels. There are 392 curves, 40 grade crossings and 593 bridges along the right-of-way as indicated in Table 4-1. The existing mainline was laid out for four-track operation over most of its length; however, in recent years at least one track has been removed, and there are a number of long sections with only two tracks (see Table 4-2). Conrail is continuing to eliminate excess trackage and is in the process of consolidating its mainline from Pittsburgh to Harrisburg to two tracks. Unfortunately, this does not mean that there will be an end-to-end, unused, two-track right-of-way available for HSR use.

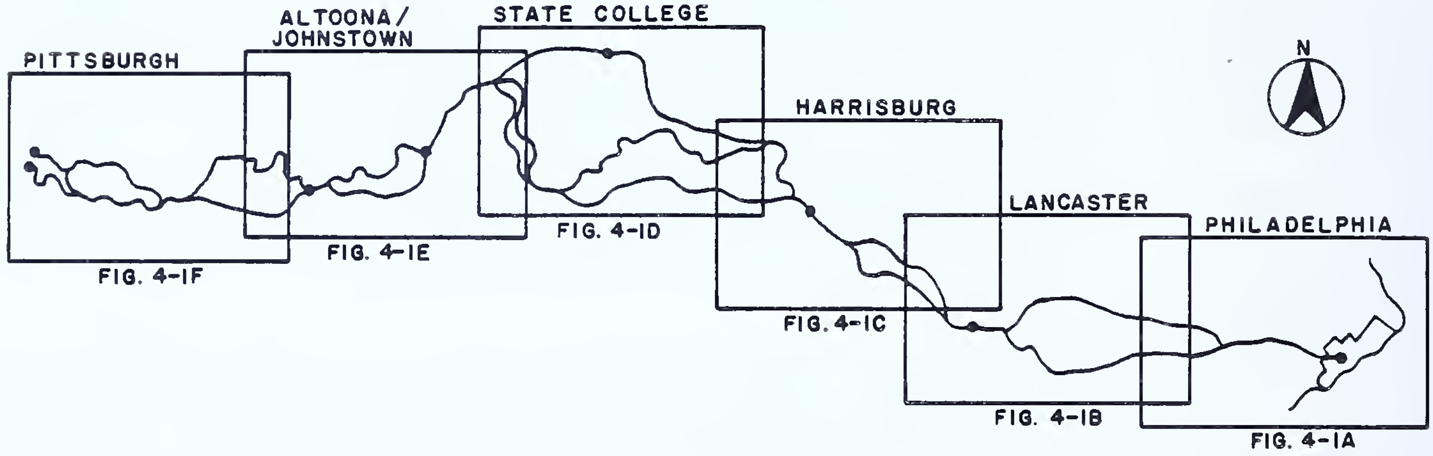
In many curves, the track alignment has been revised to provide the best geometrical fit using the entire available right-of-way width. In other words, two tracks and an access road fully occupy the space of the original four-track railroad. Modern track maintenance procedures involve the use of a vehicle access road, which in the Pennsylvania Corridor takes the space of a former track position. This implies that the existing right-of-way would need to be widened in many places to accommodate additional trackage.

The maximum speed allowed by Conrail between Harrisburg and Pittsburgh is 70 mph. The track and signal system are being upgraded to maximize operation at this speed. While certain segments of track might accommodate higher speeds, the rail system is not necessarily designed for them. The track geometry (superelevation in curves; lengths of spirals, i.e., tangent to curve transitions; and curve radii) would not generally support higher speeds without modification, and the signal block lengths are laid out for freight train safe braking distances. Blocks would probably have to be lengthened to accommodate higher speeds.

Amtrak is upgrading its electrified corridor between Harrisburg and Philadelphia to raise the maximum speed to 90 mph, through tie renewal, installation of continuous welded rail (CWR) and catenary geometry refinements.

Pennsylvania Corridor

LOCATION MAP



LEGEND

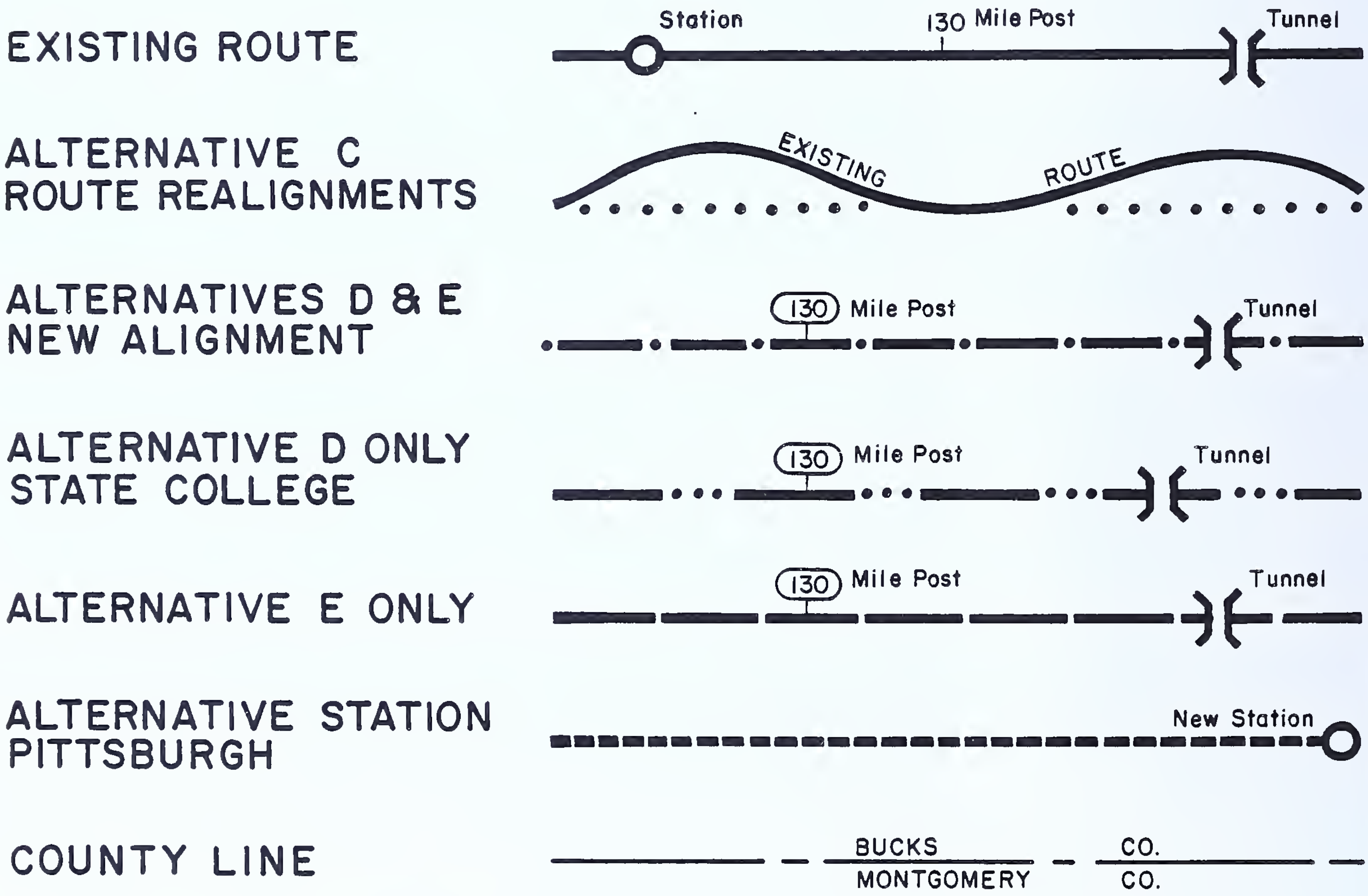
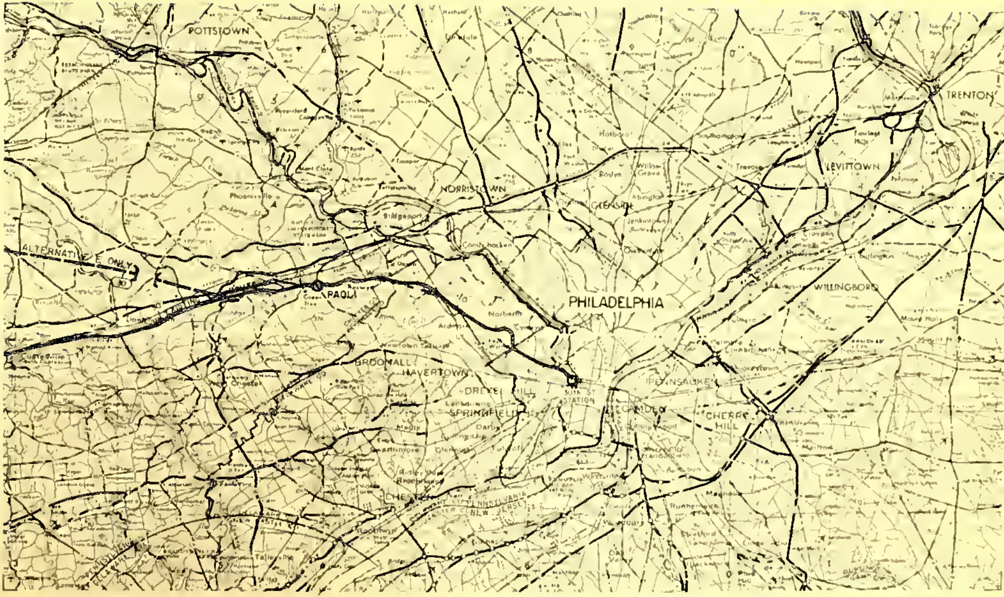
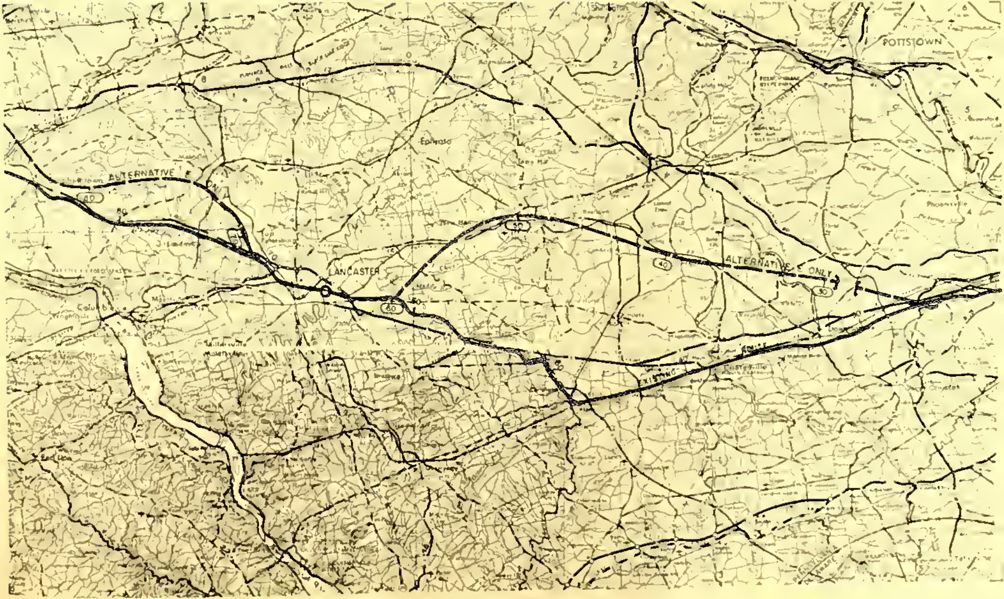


Figure 4-1 Legend
Pennsylvania Corridor Route Map



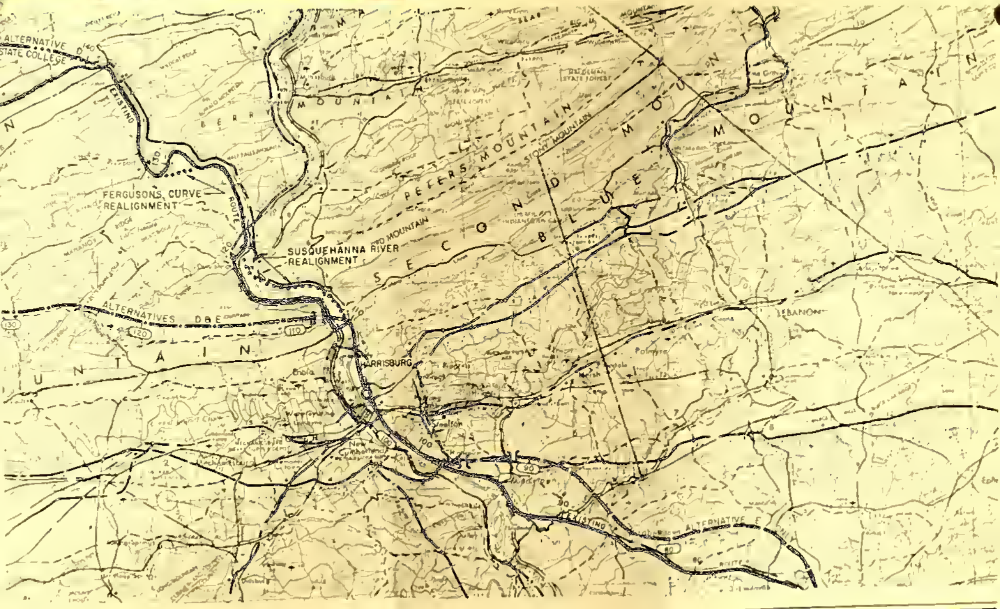
Philadelphia

Figure 4-1A
Pennsylvania Corridor Route Map



Lancaster

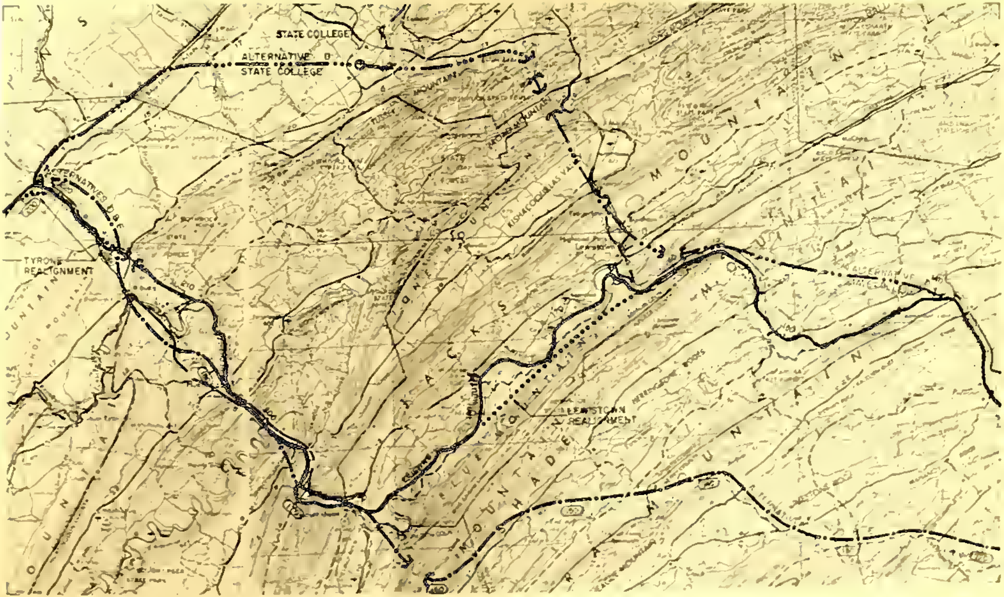
Figure 4-18
Pennsylvania Corridor Route Map



Harrisburg

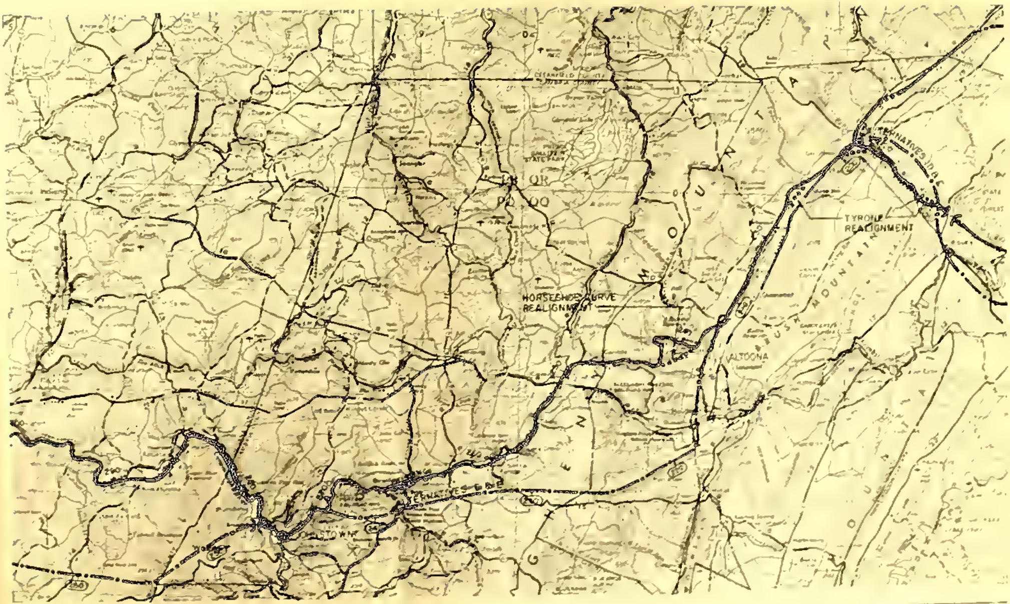
N

Figure 4
Pennsylvania Corridor Route Map



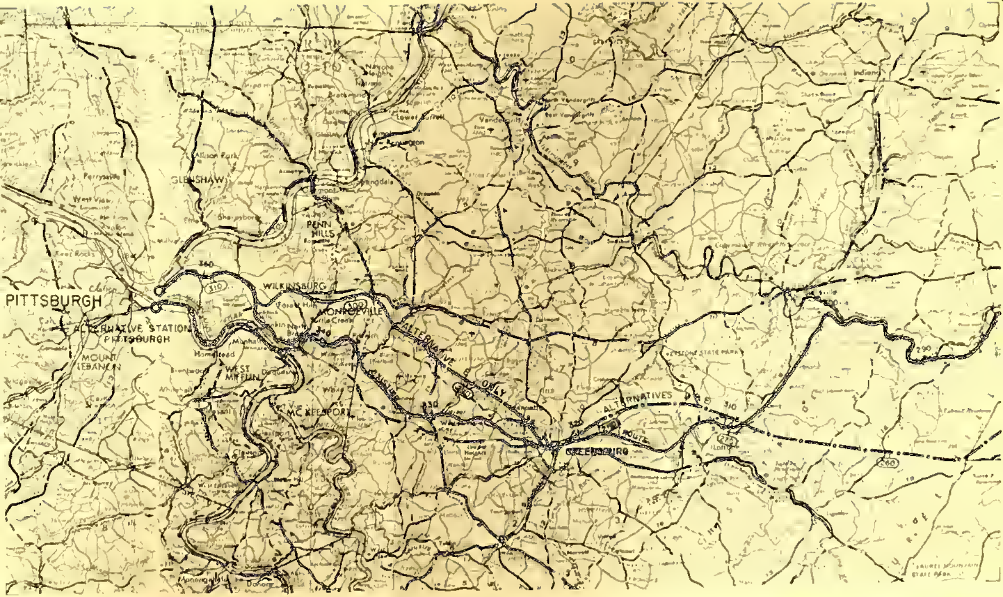
State College

Figure 4-10
Pennsylvania Corridor Route Map



Altoona/Johnstown

Figure 4-1E
Pennsylvania Corridor Route Map



Pittsburgh

Figure 4-1F
Pennsylvania Corridor Route Map

Stations	Number																			Distance (Miles)
	Curves										Grade Crossings			Bridges					Tunnels	
	Degrees													OH	Under Grade					
	0-1°	1°-2°	2°-3°	3°-4°	4°-5°	5°-6°	6°-7°	7°-8°	8°-9°	9°-10°	P	F	G		Road	Street	Drain	RR		
Philadelphia		5	3	1	3	1				1				13	8	5				8
Ardmore	3	5	4	1	1									8	26	5		1		11
Paoli	25	17	9	1	1								1	39	42	36	4			48
Lancaster	15	15	4	2		1		1			2	2		24	20	24		1		35
Harrisburg	8	24	24	6	1	2	3				8			8	11	20	7	1		62
Lewistown	4	10	14	1	1	1					8	1	4	1	6	21	9			36
Huntingdon	1	6	9	3	2	5	3				2	1	3	2	8	18	2		1	20
Tyrone	3	4	6								1			6	6	11	2			14
Altoona	6	6	12	6	8	3	1	2	1	2				16	17	26	1	1	1	39
Johnstown	5	10	15	6	3	1	2				4		2	7	14	16		1		37
Latrobe	2	3												6	8	4				10
Greensburg	2	4	3	1	3									13	9	10		1		19
Pitcairn	1		10	2	1	6	3	2					1	21	22	3	1	1		13
Pittsburgh																				
Subtotal	75	109	113	30	24	20	12	5	1	3	25	4	11	164	197	199	26	7	2	352

Legend: P = Private (no protection)
F = Flasher
G = Gate
OH = Overhead
RR = Railroad

Table 4-1

Description of Existing Corridor Physical Characteristics

TABLE 4-2

NUMBER OF TRACKS ON THE EXISTING LINE

From Mile-post	To Mile-post	Length in Miles	Route Segment	Number of Tracks
1	20	19	Philadelphia 30th Street - Paoli	4
20	32	12	Paoli - Downingtown	3
32	44	12	Downingtown - Parkesburg	4
44	94	50	Parkesburg - Royalton	2
94	119	25	Royalton - Duncannon +	3
119	291	172	Duncannon - Conpitt Junction*	3
291	336	45	Conpitt Junction - Trafford	2
336	340	4	Trafford - East Pittsburgh	3
340	353	13	East Pittsburgh - Pittsburgh	2

+ Conrail is installing TCS between Harrisburg and Altoona and plans to eliminate the third track.

* Multiple (more than three) tracks at Altoona and between Gallitzin and Cresson. Conrail is currently installing TCS in this area and plans to eliminate the third track in most of this segment.

Alternative A would continue existing service, with Amtrak continuing to provide nine trains per weekday in each direction between Philadelphia and Harrisburg, daily Philadelphia to Pittsburgh service via the Pennsylvanian, and a long distance train, The Broadway Limited, to Chicago. Amtrak owns and operates the corridor between Philadelphia and Harrisburg and operates over Conrail trackage using Conrail train and engine personnel between Harrisburg and Pittsburgh.

4.2 ALTERNATIVE B

This alternative would use existing Amtrak/Conrail trackage and facilities, upgraded for higher speed where feasible—up to 110 mph between Philadelphia and Harrisburg and 90 mph between Harrisburg and Pittsburgh. This would require track and signal system improvements to allow maximum performance from improved existing facilities. State-of-the-art diesel-powered tilt-body equipment, similar to the LRC, would be provided. (The existing electrification between Philadelphia and Harrisburg would not be used under this alternative.)

Alternative B assumes that high-speed passenger trains would operate on improved existing tracks, with little, if any, new trackage. A major drawback of this approach is the inherent incompatibility of freight and passenger operations on shared trackage. Speeds in curves would continue to be limited by track superelevation. (Particularly on Conrail trackage, superelevation would continue to be less than desirable for passenger operations.) Also, the mixing of high-speed passenger trains with freight trains raises reliability, line capacity and safety issues that would continue to limit the passenger system performance. By raising the maximum speed and curve speeds, about 2 hours could be cut from the existing timetable. Nonetheless, passenger service improvements would be severely constrained by the continuing need to share tracks with freight over major portions of the route -- one of the highest tonnage railroads in the country.

4.3 ALTERNATIVE C

This alternative would provide more substantial improvement in trip times and service reliability through larger investments in infrastructure and rolling stock. New right-of-way would be purchased to accommodate additional trackage and curve or route realignment.

A schematic plan of the proposed track changes under this alternative is shown in Figure 4-2. Two existing tracks between Philadelphia and Harrisburg would be upgraded to provide up to 110 mph capability and new trackage would be added to accommodate local freight operations on the mainline between Parkesburg and Royalton. West of Harrisburg, one to two new tracks would be constructed, providing for up to 110 mph operation. These would be built within the existing right-of-way, space permitting, but in some locations additional right-of-way would have to be acquired. The detailed locations where existing right-of-way might be used or where new right-of-way would have to be acquired have not been identified specifically yet, nor discussed with the existing property owners. If Alternative C is selected for further study, this necessary site-specific route investigation will be made in Phase 2. In other locations, where it is not feasible to add more than one new dedicated passenger track, either within the existing right-of-way or by widening it (estimated to be up to about 50 percent of the entire length), only one new high-speed

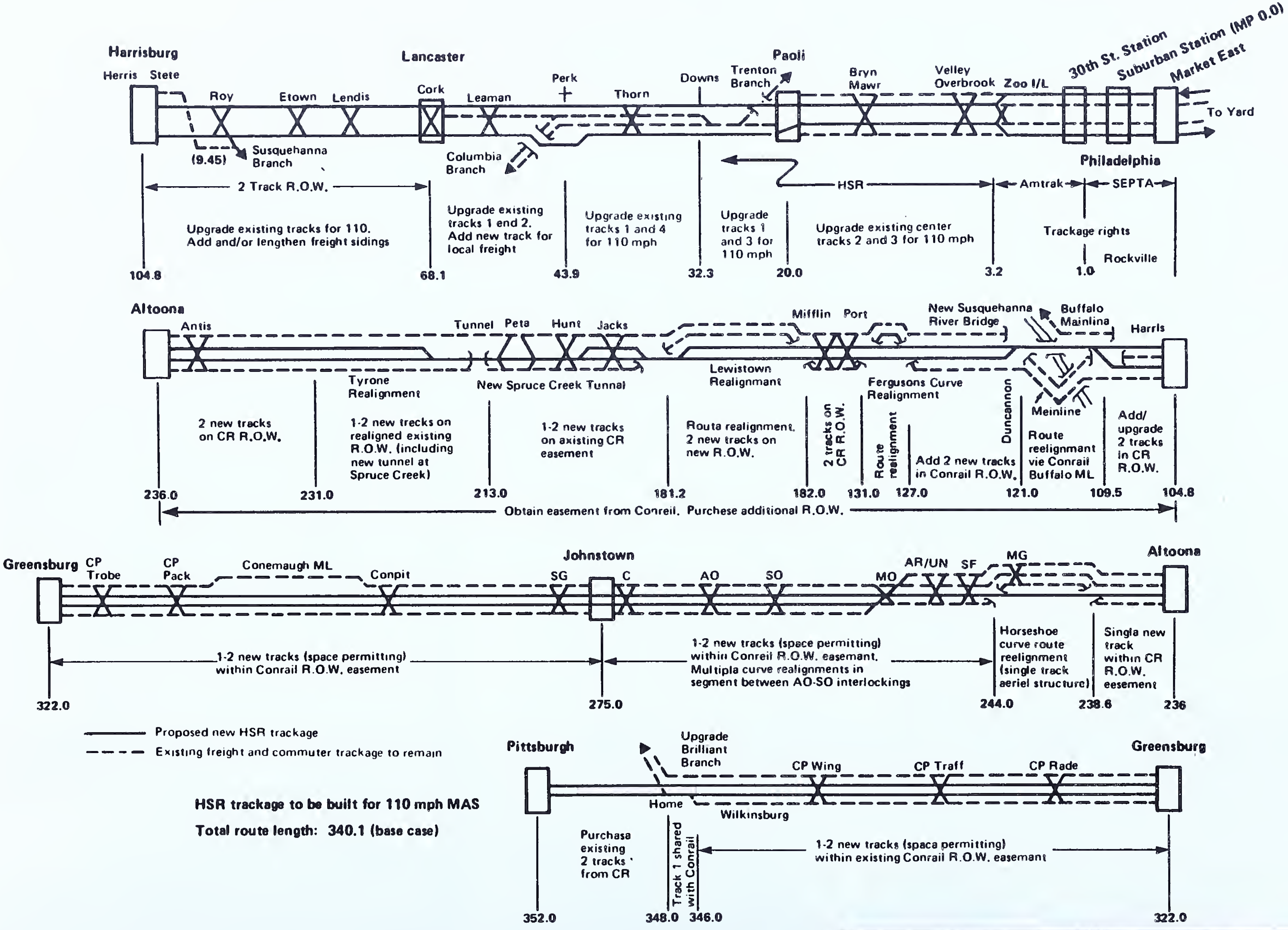

Harrisburg
Herris
Stete
Roy
Etown
Lendis
Lancaster
Cork
Leaman
Perk
Thorn
Downs
Trenton Branch
Paoli
Bryn Mawr
Velley Overbrook
Zoo I/L
30th St. Station
Suburban Station (MP 0.0)
Market East
To Yard
(9.45)
Susquehanna Branch
Columbia Branch
Philadelphia
2 Track R.O.W.
HSR
Amtrak
SEPTA
Upgrade existing tracks for 110. Add and/or lengthen freight sidings
Upgrade existing tracks 1 end 2. Add new track for local freight
Upgrade existing tracks 1 and 4 for 110 mph
Upgrade tracks 1 and 3 for 110 mph
Upgrade existing center tracks 2 and 3 for 110 mph
Trackage rights
Rockville
104.8
68.1
43.9
32.3
20.0
3.2
1.0
Altoona
Antis
Tunnel
Peta
Hunt
Jacks
Mifflin
Port
New Susquehanna River Bridge
Buffalo Mainlina
Harris
Tyrone Realignment
New Spruce Creek Tunnel
Lewistown Realignment
Fergusons Curve Realignment
Duncannon
Meinline
2 new tracks on CR R.O.W.
1-2 new trecks on realigned existing R.O.W. (including new tunnel at Spruce Creek)
1-2 new tracks on axisting CR easement
Route realignment, 2 new tracks on new R.O.W.
2 tracks on CR R.O.W.
Route realignment
Add 2 new tracks in Conrail R.O.W.
Route reelignmant vie Conrail Buffalo ML
Add/ upgrade 2 tracks in CR R.O.W.
236.0
231.0
213.0
181.2
182.0
131.0
127.0
121.0
109.5
104.8
Obtain easement from Conreil. Purchese additional R.O.W.
Greensburg
CP Trobe
CP Pack
Conemaugh ML
Conpit
Johnstown
SG
C
AO
SO
MO
AR/UN
SF
MG
Altoona
1-2 new tracks (space permitting) within Conrail R.O.W. easement
1-2 new tracks (space permitting) within Conreil R.O.W. easemant. Multipla curve realignments in segment between AO-SO interlockings
Horseshoe curve route reelignment (single track aeriel structure)
Singla new track within CR R.O.W. eesement
322.0
275.0
244.0
238.6
236
Proposed new HSR trackage
Existing freight and commuter trackage to remain
HSR trackage to be built for 110 mph MAS
Total route length: 340.1 (base case)
Pittsburgh
Upgrade Brilliant Branch
Home
Wilkinsburg
CP Wing
CP Traff
CP Rade
Greensburg
Purchasa existing 2 tracks from CR
Track 1 shared with Conrail
1-2 new tracks (spaca permitting) within existing Conrail R.O.W. easemant
352.0
348.0
346.0
322.0

Figure 4-2
Alternative C
Schematic Plan

track would be built. The equivalent of 1.5 additional tracks dedicated to HSR service is proposed for the entire length between Harrisburg and Pittsburgh. At least hourly service could be accommodated under this scheme by providing high-speed turnouts at each end of the single-track segments.

An analysis of existing curve restrictions led to the identification of 15 possible route realignments and 77 possible curve realignments. These route improvement candidates, however, cannot be considered independently. Choosing a particular route realignment in some cases eliminates multiple curves, thus dropping them from the curve realignment list; in other cases, alternate route alignments are considered in the same or overlapping segments of the route, which requires selecting the best one for further study.

In final form, five route realignments and 40 curve realignments were included in the proposed Alternative C. The adjusted route length is 340 miles. The five proposals, listed in Table 4-3 and shown schematically in Figure 4-2, are briefly described below. The time saving associated with each route realignment represents the calculated difference in trip time between operating a tilt-body train over the realigned route at up to nine inches of cant deficiency (unbalanced elevation) compared with the existing operation, which reflects no more than three inches of unbalance. With the exception of these five realignments, Alternative C follows the existing Amtrak/Conrail mainline.

An additional benefit which would result from these route realignments is that they would mitigate occasional high-water problems along the existing route in the flood plains. Local flooding has in the past disrupted rail operations in low-lying segments of the present alignment. The proposed realignments are all on higher ground.

4.3.1 Alternative C - Proposed Route Realignments

1) Susquehanna River

The existing route crosses the Susquehanna River at Rockville, near MP 110, and travels along the western side of the river to Duncannon, near MP 121, where it then follows the Juniata River. The speed through this 11.5-mile stretch of track averages only about 45 mph due to a sharp left curve on the east side of the Rockville Bridge and a sharp left followed by a right beginning near MP 109.5.

A major realignment would involve constructing a new track on the Conrail right-of-way along the eastern side of the Susquehanna for approximately nine more miles before crossing the river on a new bridge near Duncannon. With two curves of about 3 degrees, this line would have an average speed of about 95 mph, and would be about 1.8 miles shorter than the existing alignment, saving about 9 minutes of trip time.

This option would entail building a new railroad bridge about 4,750 feet long over the Susquehanna River and about nine miles of track on the eastern side of the river, with grade separations (flyovers) at Rockville and Duncannon (see Figure 4-3). The existing Harrisburg-Buffalo mainline track

TABLE 4-3

ALTERNATIVE C PROPOSED ROUTE REALIGNMENTS

Location	MP-MP	Existing Length (miles)	Realigned Length (miles)	Existing Travel Time+ (min.)	Realigned Travel Time* (min.)	Estimated Time Savings (minutes)
Susquehanna	109.5-121.0	11.5	9.7	15.3	6.3	9.0
Ferguson's Curve	127.0-131.0	4.0	3.0	4.0	1.7	2.3
Lewistown	162.0-181.2	19.2	15.6	20.9	8.6	12.3
Tyrone	213.0-231.0	18.0	17.5	27.0	11.7	15.3
Horseshoe Curve	238.6-244.0	5.4	3.6	9.3	3.0	6.3
TOTALS		58.1	49.4	76.5	31.3	45.2

+ Based on 3 inches unbalance

* Based on 9 inches unbalance

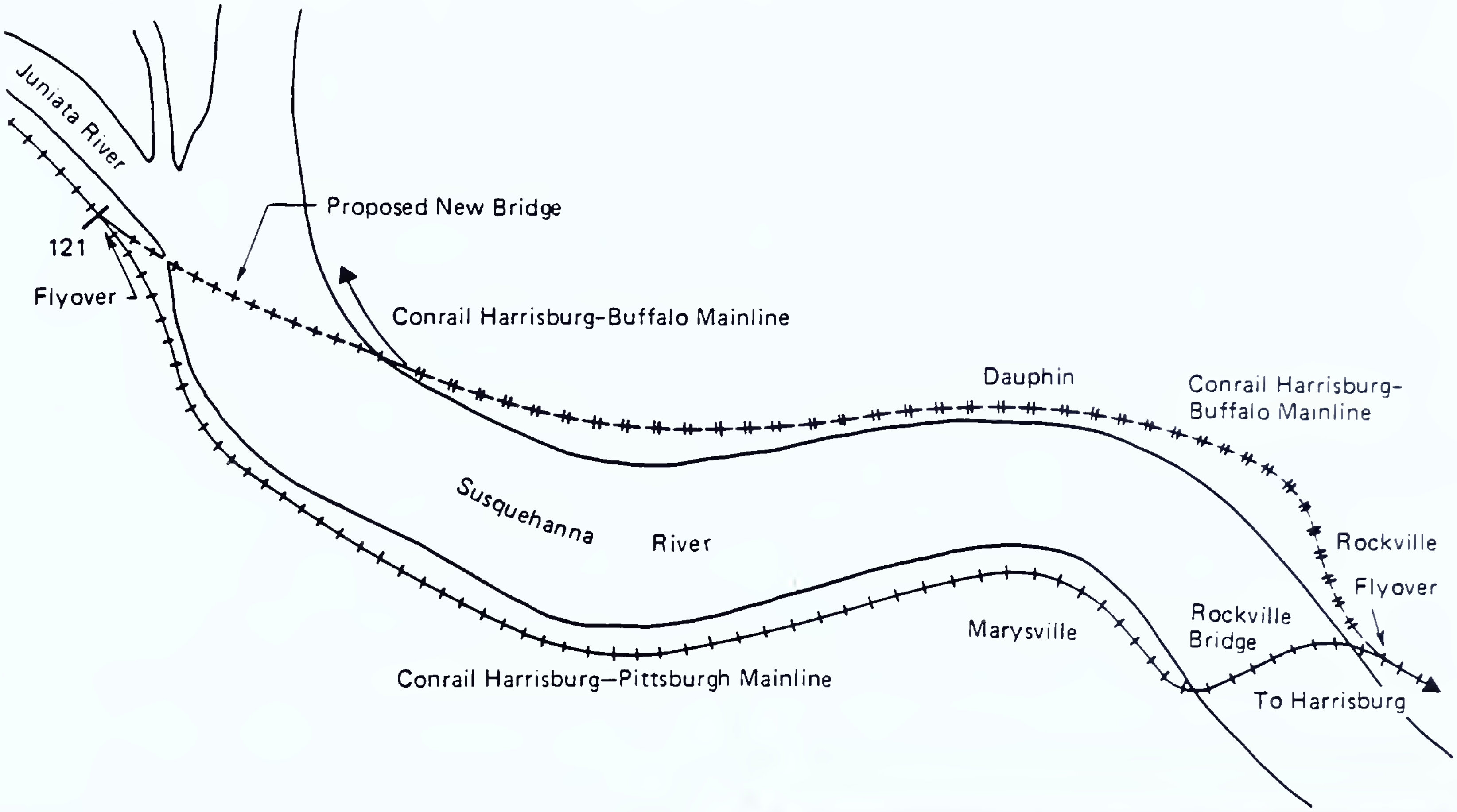

Juniata River
Proposed New Bridge
121
Flyover
Conrail Harrisburg-Buffalo Mainline
Dauphin
Conrail Harrisburg-Buffalo Mainline
Susquehanna River
Rockville
Flyover
Rockville Bridge
Marysville
To Harrisburg
Conrail Harrisburg–Pittsburgh Mainline
Legend
Existing Alignment
Existing Milepost
100
Proposed New Construction
Proposed New Construction and Conrail Realignment
N

Figure 4-3
Susquehanna River Crossing at Duncannon

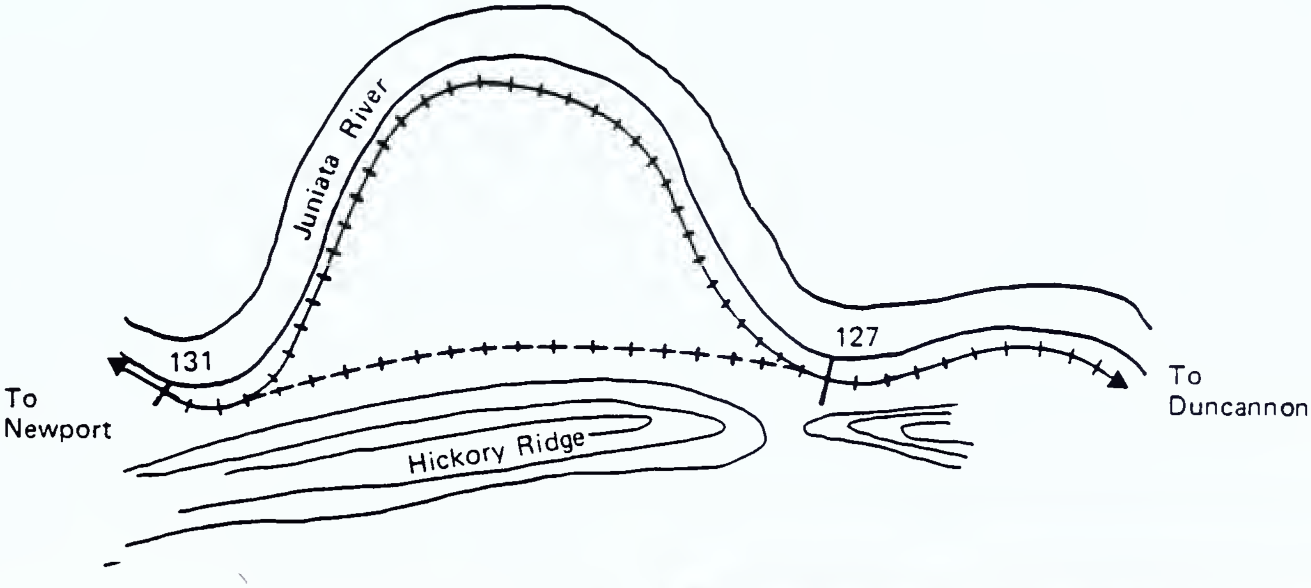


Figure 4-4
Ferguson's Curve Route Realignment

would remain separate, and the right-of-way would be widened to accommodate the new high-speed passenger track.

2) Ferguson's Curve

Ferguson's Curve (Figure 4-4) is located along the Juniata River, just east of Newport, between MP 127.0 and 131.0. The existing alignment begins with a 2-degree 57-minute curve to the right, followed by a 2-degree 15-minute curve left, and ends with a 1-degree 24-minute curve to the right. The existing grades are minimal. The maximum speed along this alignment is currently 60 mph.

The proposed realignment would leave the existing right-of-way near MP 127, rejoin it at MP 131, and would be about 3 miles long. The new section would require 3 percent grades to get over the ridge and flyovers at both ends since freight would continue to use the existing route. The proposed design speed over the candidate realignment, which would be a mile shorter than the existing route, would be 110 mph, saving about 2.3 minutes of trip time.

Constructing the Ferguson's Curve realignment would entail moving approximately 1.3 million cubic yards of earth, building three highway bridges, each approximately 75 feet long, and two flyovers.

3) Lewistown

The existing alignment near Lewistown winds along the Juniata River for 19.2 miles, twice crossing the river (see Figure 4-5). Currently, the average speed over this section is about 55 mph, with a maximum of 45 mph on the sharp left curves starting at MP 165.2 and MP 165.8.

The proposed realignment would be 15.5 miles long and would have no significant curves. It would leave the existing right-of-way on a flyover at MP 162, travel southwest along Blue Mountain, and rejoin the right-of-way on a flyover at MP 181.2. Although the grade would be about 1.5 percent in several places and hit 3 percent for 0.75 miles, a speed of 110 mph could be attained over the majority of the realigned route. This shortcut would save 12 minutes.

Constructing the proposed Lewistown realignment would entail moving approximately 4.4 million cubic yards of earth and placing about 15.5 miles of double track and new signals. In addition, a 100-foot railroad bridge would be needed near MP 177.1 to cross a major road, eight 50-foot railroad bridges would cross various smaller roads, one 100-foot highway bridge would be needed near MP 175.2, and two railroad grade separations would need to be built.

4) Tyrone

The proposed Tyrone realignment begins at MP 213 and ends at MP 231 (see Figure 4-6). As configured it is actually more a series of major curve

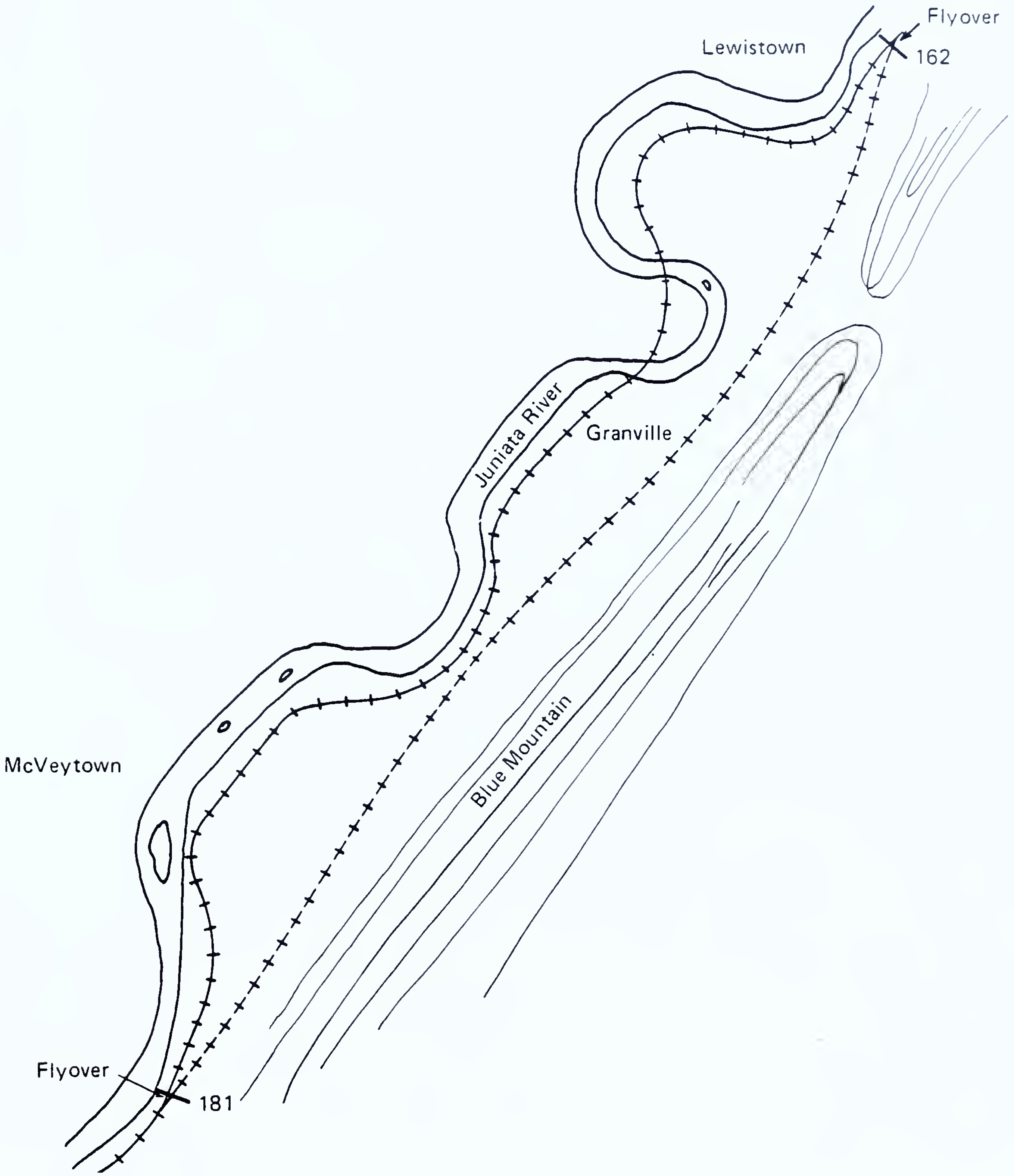


Figure 4-5
Lewistown Route Realignment

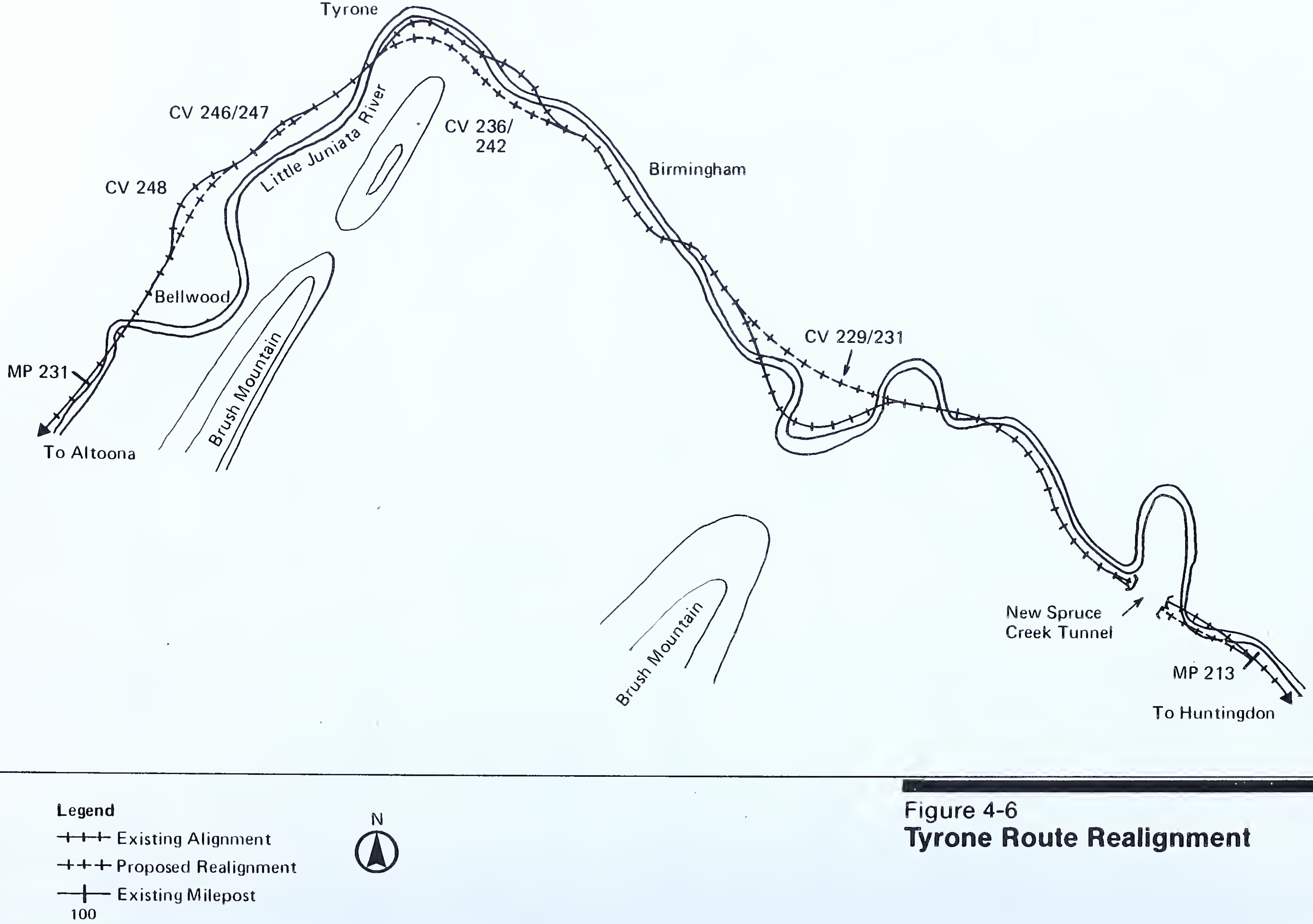


Figure 4-6
Tyrone Route Realignment

realignments than a single route realignment; however, it was useful to group them together for purposes of analysis. The existing alignment along the winding Little Juniata River has three curves in excess of six degrees and five more over five degrees. In addition, there is a pair of single track tunnels at Spruce Creek, which acts as a bottleneck. The average speed along this alignment is currently about 40 mph.

Rerouting would involve widening and straightening the existing right-of-way and building a third single-track tunnel at Spruce Creek. The average speed for the realignment would be about 95 mph, saving more than 15 minutes of trip time.

Construction along the new alignment would entail about 6.8 million cubic yards of earthwork (cut to fill), boring a new 2600-foot single-track tunnel, building four 100-foot undergrade bridges, building and/or realigning about 12 miles of 4-track route, and reconfiguring the existing interlockings at Tunnel and CP Wilson Gray.

5) Horseshoe Curve

This proposed realignment would bypass the section of track from MP 238.6 to MP 244 up the face of the Allegheny Escarpment (see Figure 4-7). The existing alignment at this location has one curve of 9 degrees 25 minutes and five more curves of at least 6 degrees. The grade ranges from 1.75 to 1.86 percent. Maximum speed on the existing alignment is 35 mph.

The proposed realignment, about 3.5 miles long, would have a steady grade of 3 percent and no significant curves. The proposed average speed would be 75 mph, saving about 6.3 minutes of trip time.

The new alignment would require roughly 3.5 miles of aerial structure linking the existing MP 238.6 with existing MP 244, and a small amount of cut and fill. The junctions at both ends of the realignment would be grade separated.

4.3.2 Alternative C - Curve Realignments

The curve realignments included in the base case Alternative C are listed in Table 4-4. Each would involve widening and straightening the existing right-of-way to provide less restrictive curves than exist today. Most would involve shifting existing freight tracks as well as providing space for straighter passenger train trackage. Some would require extensive earthwork and new structures, e.g., bridges, retaining walls and culverts.

4.3.3 Alternative C - Operating Assumptions

For the purposes of the alignment studies, it was assumed that a Pennsylvania High Speed Rail operating entity would purchase the Amtrak mainline from Philadelphia to Harrisburg and lease or acquire an easement over the Conrail

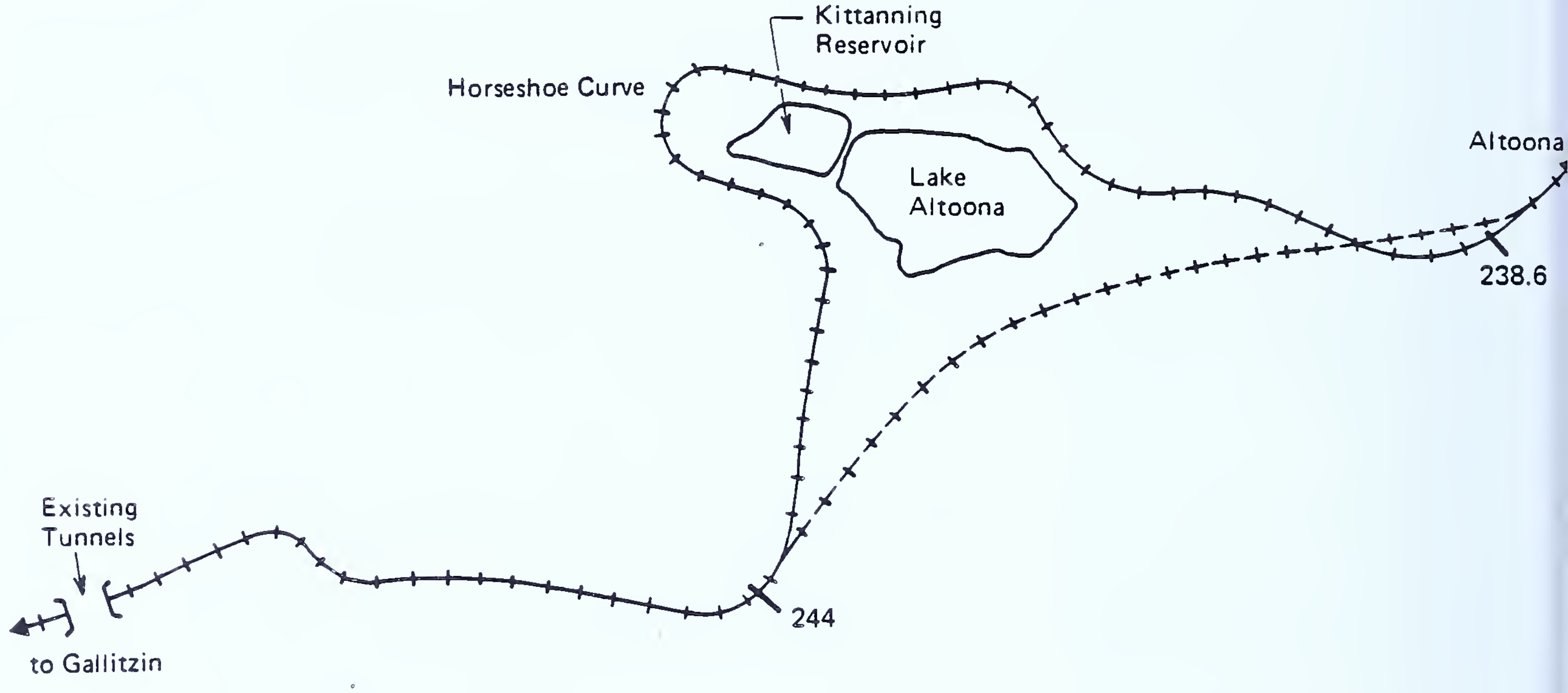


Figure 4-7
Horseshoe Curve Route Realignmen

TABLE 4-4

CANDIDATE CURVE REALIGNMENTS

Curve No.	Location (MP-MP)	Existing D_c	Realigned D_c
54	47.40 - 48.18	2° - 00' R	1° - 30' R
60	52.05 - 52.50	4° - 00' R	1° - 30' R
61	52.80 - 53.20	2° - 07' L	1° - 45' R
68	59.98 - 60.56	2° - 07' R	1° - 30' R
135	125.18 - 125.62	2° - 00' L	1° - 30' L
136	126.01 - 126.62	2° - 04' L	1° - 30' L
148	137.95 - 139.00	2° - 56' L	1° - 30' L
151	140.60 - 141.01	2° - 06' L	1° - 00' L
153	141.85 - 142.19	2° - 45' R	2° - 15' R
159	147.50 - 148.08	2° - 30' R	2° - 10' R
163	152.54 - 153.00	3° - 15' R	2° - 15' R
164	153.05 - 153.50	5° - 00' L	2° - 15' L
165	153.91 - 154.24	4° - 11' L)	2° - 15' L
170	157.34 - 157.72	3° - 34' L)	
171	157.89 - 158.12	1° - 07' L	1° - 15' L
196	182.61 - 183.51	5° - 00' L	1° - 00' L
197	183.75 - 184.10	2° - 00' R	1° - 00' R
203	192.60 - 193.19	2° - 15' L	1° - 00' L
216	204.16 - 204.53	2° - 22' L	1° - 00' L
218	206.10 - 206.50	3° - 45' L	1° - 54' L
219	206.79 - 207.30	2° - 45' R	2° - 15' R
220	207.33 - 207.72	2° - 45' L	1° - 54' L
270	244.72 - 244.90	9° - 15' L)	1° - 25' L
271	244.95 - 245.10	3° - 30' R)	
272	245.12 - 245.31	6° - 00' L	0° - 45' L
291	264.50 - 264.91	4° - 24' R	2° - 15' R
292	264.96 - 265.28	3° - 50' L	2° - 15' L
293	265.69 - 266.00	3° - 50' R	2° - 15' R
294	266.32 - 266.79	4° - 39' L	2° - 05' L
296	267.35 - 267.69	6° - 12' L	1° - 54' L
301	269.40 - 269.56	4° - 33' R	1° - 54' R
302	269.64 - 269.95	4° - 06' L)	2° - 17' R
303	270.03 - 270.32	6° - 34' R)	
304	270.42 - 270.70	6° - 18' L	0° - 45' R
305	270.72 - 271.07	6° - 38' R	2° - 15' R
306	271.33 - 271.56	5° - 29' R	1° - 30' R
323	279.70 - 279.98	3° - 33' R	2° - 15' R
324	280.00 - 280.30	2° - 25' L	2° - 15' L
352	309.14 - 309.60	2° - 00' R	1° - 30' R

territory between Harrisburg and Pittsburgh. Amtrak would cease to operate cross-state rail service in the Corridor, except for long-distance train service to points outside the state. SEPTA commuter service and freight in the corridor would continue to operate substantially as today, except for coordination with HSR and joint use of station-area tracks.

Over one short segment of the route, through freight service is proposed to be diverted to alternate trackage. Between Home Interlocking (MP 347.8) and Pittsburgh (MP 353), it is proposed that freight be diverted to the Brilliant Branch to permit nonconflicting use of the existing two-track railroad between those points by passenger trains. The Brilliant Branch would be substantially upgraded as a project cost to accommodate the relocated through freight service, and local freights would utilize the existing mainline to serve industries.

Passenger trains would have exclusive use of separate, dedicated trackage west of Harrisburg except in the areas of passenger stations and over one short piece of the Conrail mainline between Wilkinsburg and Homewood, where space restrictions created by the PAT busway in the former railroad right-of-way would preclude adding more than one additional dedicated passenger track. In this segment, one track would be used solely for freight, one would be shared (passenger and freight) and one would be reserved for passenger service only.

4.4 ALTERNATIVE D

The objectives of this alternative were to identify the straightest possible route between Philadelphia and Pittsburgh while providing service to Lancaster, Harrisburg, Altoona, Johnstown, and Greensburg; to minimize the impact to existing developed areas and the natural environment; and to achieve these objectives in a cost-effective manner. It was desired to achieve the lowest possible trip time end to end, using advanced train technology, consistent with the environmental and cost considerations.

A trial-and-error method was used to identify this new alignment. Starting from 1:250,000 scale topographic maps, a number of possible "shortest line" routes were plotted. Then each was transferred to 1:24,000 scale maps and further refined. At this scale, it was possible to identify existing urban development and natural topographic features (limited by the revision date of each map). The plots were made manually by engineers experienced in developing route alignments, who were careful to minimize environmental impact, while observing conceptual design constraints. In some cases, several alignments were evaluated between two intermediate points; in other cases there was an obvious "best" alignment. The final conceptual alignment was entered in a computer file to aid in plotting profiles and calculating earthwork quantities and bridge lengths.

The base case alignment for Alternative D uses the existing right-of-way between Philadelphia and Harrisburg and from Greensburg to Pittsburgh. Between Harrisburg and Greensburg, the proposed HSR line follows a new alignment, except in the vicinity of Altoona and Johnstown stations. (Refer to the maps provided in Figure 4-1 for a more definitive routing.)

As originally conceived, Alternative D would not have followed the existing railroad line as much as it does. An analysis of the marginal trip time savings, high cost and large environmental impact of a new alignment in the Philadelphia to Harrisburg and Greensburg to Pittsburgh segments, however, persuaded the study team to propose using the existing right-of-way.

A schematic track plan of Alternative D is shown in Figure 4-8. As conceived, a full two-track railroad would be built end-to-end. A maximum speed of 160 mph was planned wherever the alignment would permit. (A top speed of 180 mph was also analyzed, but the effects of grade and curvature severely limit the marginal trip time savings achievable by raising the maximum speed.) The 314-mile-long route would support an end-to-end trip time of 3 hours and 16 minutes with six intermediate stops.

4.4.1 Alternative D — Alternate Routings

An alternative routing via Lewistown, State College and Tyrone (Alternative D--State College) was also developed. It would share the existing Conrail right-of-way with freight service between Harrisburg and Millerstown and would include the Susquehanna River and Ferguson's Curve route realignments. Between Millerstown and Tyrone, the route would follow a new alignment via State College on a new right-of-way. A portion of the route would use the Bald Eagle Branch right-of-way from a point just south of Port Matilda to Tyrone.

An alternative to serving downtown Pittsburgh at the site of the existing Amtrak station would be to upgrade the existing Port Perry Branch in East Pittsburgh (MP 341) with a connection to the Pittsburgh and Lake Erie (P&LE) Railroad across the Monongahela River to a new station at Station Square (the historic P&LE Terminal currently redeveloped into commerical space).

4.4.2 Alternative D — Segment Descriptions

All crossings would be grade separated, and the entire right-of-way would be fenced.

Philadelphia - Lancaster

West of Zoo Interlocking, HSR would use mainline tracks 2 & 3 to Paoli, upgraded for high speed service (new continuous welded rail, concrete ties, 15-foot track centers, where possible, and fully fenced, except in interlockings). Existing interlockings would be retained to provide operational flexibility for emergency use by SEPTA, Amtrak or Conrail trains in the Corridor.

At Paoli, a new high-level island platform and station would be built to the west of the existing commuter station.

Between Paoli and Downingtown, HSR would use existing Tracks 1 and 3 upgraded for 160 mph service. Between Downingtown and Parkesburg, HSR would operate on upgraded tracks 1 and 4, reserving the center two tracks (2 and 3) for Conrail freight service.

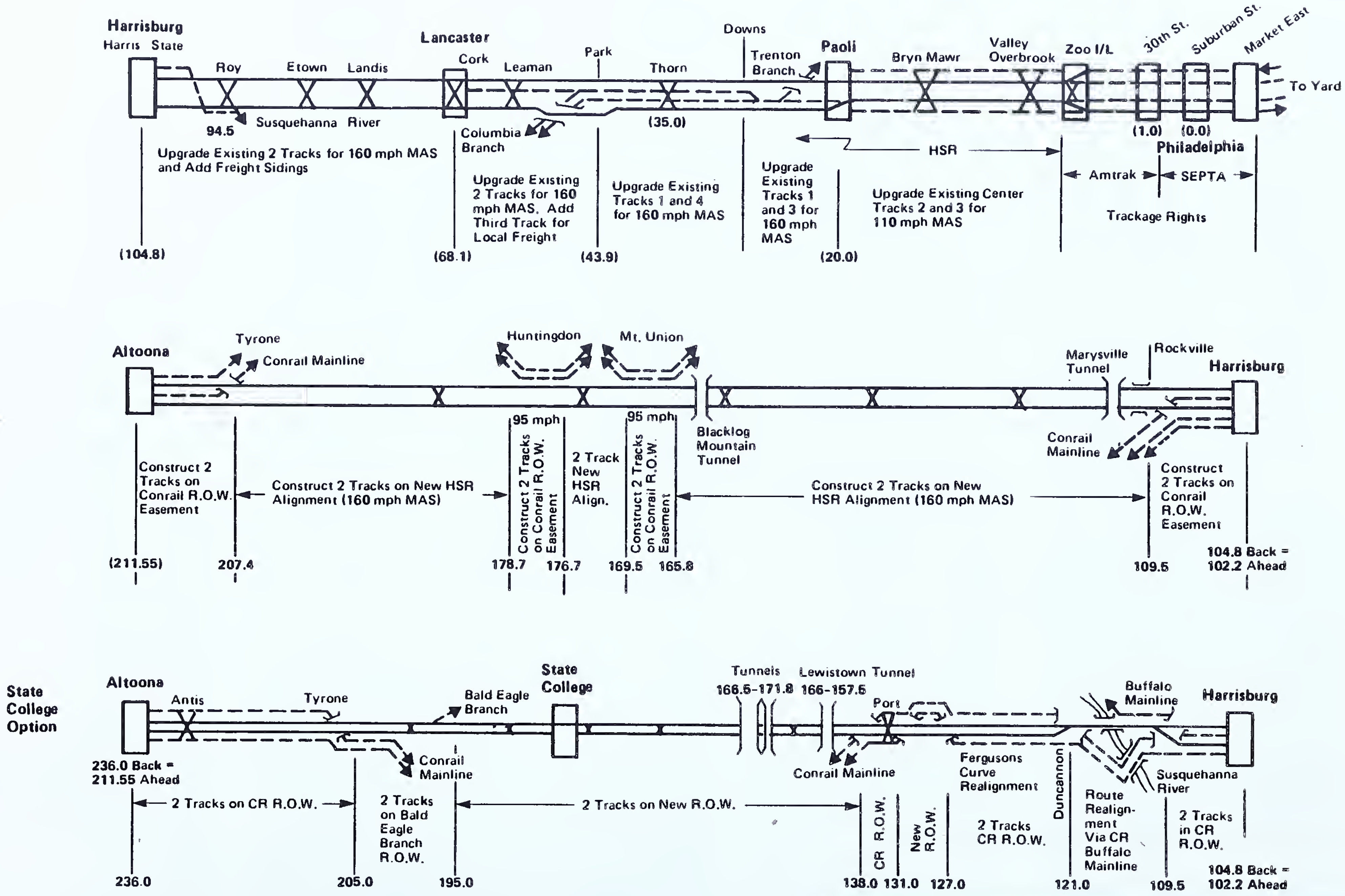


Figure 4-8
Alternative D—Schematic Plan

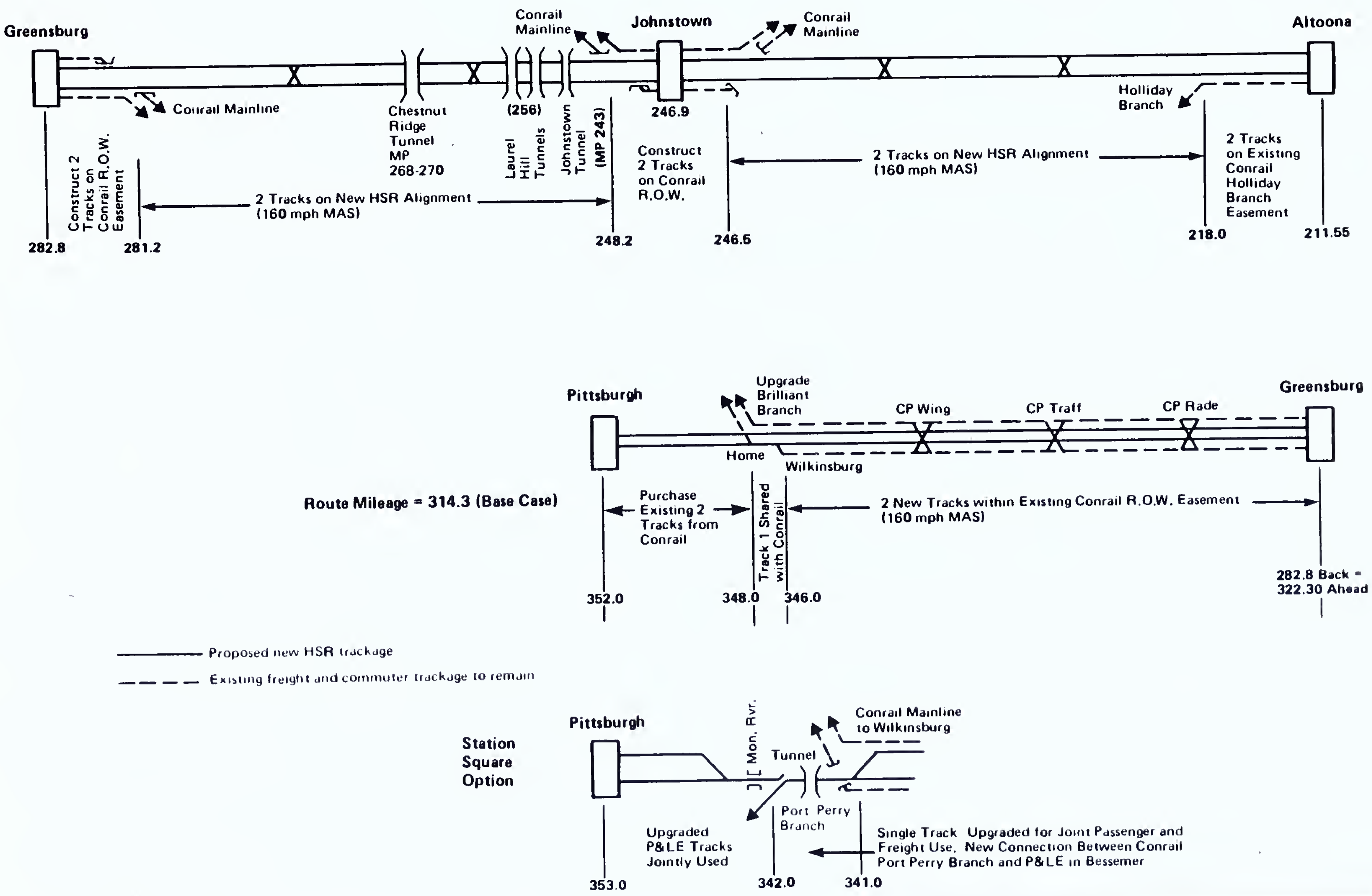

Greensburg
Conrail Mainline
Johnstown
Conrail Mainline
Altoona
Conrail Mainline
Chestnut Ridge Tunnel MP 268-270
(256)
Laurel Hill Tunnels
Johnstown Tunnel
(MP 243)
246.9
Holliday Branch
Construct 2 Tracks on Conrail R.O.W. Easement
2 Tracks on New HSR Alignment (160 mph MAS)
Construct 2 Tracks on Conrail R.O.W.
2 Tracks on New HSR Alignment (160 mph MAS)
2 Tracks on Existing Conrail Holliday Branch Easement
282.8
281.2
248.2
246.6
218.0
211.55
Pittsburgh
Upgrade Brilliant Branch
CP Wing
CP Traff
CP Rade
Greensburg
Home
Wilkinsburg
Route Mileage = 314.3 (Base Case)
Purchase Existing 2 Tracks from Conrail
Track 1 Shared with Conrail
2 New Tracks within Existing Conrail R.O.W. Easement (160 mph MAS)
352.0
348.0
346.0
282.8 Back = 322.30 Ahead
Proposed new HSR trackage
Existing freight and commuter trackage to remain
Station Square Option
Pittsburgh
Mon. Rvr.
Tunnel
Conrail Mainline to Wilkinsburg
Port Perry Branch
Upgraded P&LE Tracks Jointly Used
Single Track Upgraded for Joint Passenger and Freight Use. New Connection Between Conrail Port Perry Branch and P&LE in Bessemer
353.0
342.0
341.0

Figure 4-8 (continued)
Alternative D—Schematic Plan

Between Parkesburg and Lancaster, a third track would be built within the existing right-of-way to accommodate local freight service. Park, Leaman and Cork interlockings would be reconfigured. Curves between Atglen and Christiana, Gap and Kinzer, and at Ronks would be realigned.

Lancaster - Harrisburg

West of Lancaster, the existing two passenger tracks would be upgraded for 160-mph service. Local freight and long-distance Amtrak service would continue to be accommodated. Freight sidings would be added as required to service local industry without conflicting with HSR operations. Most through freight would be diverted to the former Reading line.

One island high-level platform would be built at the Amtrak station in Harrisburg and dedicated to HSR service.

Harrisburg - Altoona

Between Harrisburg and Altoona, HSR service would be provided on a new alignment identical except in gradient to the one proposed and discussed below for Alternative E. The route would cross the Susquehanna on a new bridge north of the existing Rockville bridge, run under downtown Marysville in a cut-and-cover tunnel, and then head west as shown on the map, Figure 4-1.

Grades are not envisioned to exceed 3.5 percent; therefore, the vertical profile would differ from the proposed Maglev alignment, requiring deeper cuts and more tunneling than the Maglev alternative. A two-track, high-speed, dedicated-track railroad is proposed for the entire length. New universal interlockings with high-speed turnouts would be built at approximately 25-mile intervals. The line would be electrified at 25 kV, 60 Hz, with new signals and centralized control. West of Marysville the new railroad would run along the base of Cove Mountain, at about the 700 ft elevation line, providing 160 mph capability all the way to Mount Union. A tunnel would be required under Blacklog Mountain to avoid extensive route circuity. The proposed line crosses the Juniata River about two miles southeast of Mount Union and remains elevated over Boro Line Road and onto the Conrail mainline right-of-way at about MP 189.3. The speed through Mount Union would be restricted to 95 mph to avoid affecting the settled area.

The proposed line then proceeds west at grade on the Conrail right-of-way for roughly 2.5 miles through Jacks Narrows, following the Juniata River. It curves right on an elevated structure over the river, over a quarry, crossing over the river again, and then over the railroad, headed north toward Huntingdon.

The line would then run along the southern shore of the river up to about two miles southeast of Huntingdon, cross the river, and follow the Conrail right-of-way at grade through Huntingdon (up to approximately MP 203.6). The speed through Huntingdon would be restricted at 95 mph as through Mount Union. There it would curve to the left on an elevated structure over the river and up a ravine just to the north of the state prison. Then it would run at grade up hill through undeveloped land and in a cut adjacent to an abandoned strip mine. It would cross Route 22 about 1.5 miles south of Alexandria on an elevated structure and run parallel with Route 22 for three miles, through the gap near Alfarata. It would cross over the highway just east of Water Street and run north at grade up the hill on the east side of Highway 350, avoiding as much as possible the adjacent agricultural land.

The proposed alignment skirts Sinking Valley, running north over the Little Juniata River near Spruce Creek and then curving west, north of Birmingham, to Tyrone after passing through a 4,000-foot-long tunnel under Bald Eagle Mountain. The line would converge with the existing Conrail right-of-way at about MP 222 enroute to Altoona. The line would be built mostly at grade in this segment, generally within the Conrail right-of-way, with a flyover at Altoona yard to avoid interference with freight operations. A new high-level island platform would be built at Altoona.

Where the line would use portions of the existing Conrail right-of-way between Harrisburg and Rockville, at Mount Union and Huntingdon, and between Tyrone and Altoona, provisions would be made for entering and exiting the right-of-way with grade-separated connections to prevent operational interference with Conrail freight service.

Altoona - Johnstown

Between Altoona and Johnstown, a new HSR alignment is proposed as shown in Figure 4-1. The line would require an easement over the lightly-used Holliday Branch between Altoona and Duncansville, with accommodation for freight traffic. The line would run parallel to, or in the median of, new Route 220 for a few miles before heading west over the Allegheny Front through the Blue Knob-Trout Run corridor. Approaching Johnstown, the line would be built on an elevated structure to cross the Little Conemaugh River and Conrail mainline, coming down within the railroad right-of-way about 2.5 miles east of the Amtrak station.

Johnstown - Greensburg

The segment from Johnstown to Greensburg would be built mostly on a new alignment. The line would follow the Conrail alignment for roughly one-half mile to the northwest, crossing over the river and highway. Rising on a cut along the side of the Brownstown hill, the line would curve to the left, continuing to rise and then pass through two 0.5- to 0.75-mile-long cut-and-cover tunnels to avoid deep open cuts to the west of Brownstown, avoiding what would otherwise be an eyesore to the community. The line would then continue west at grade up to Laurel Hill where a 0.75-mile-long tunnel would be required. From there west, the alignment gently winds through the hills, skirting south of Derry, crossing over the Conrail mainline at Bradensville. The line approaches Greensburg from the northeast, joining the Conrail mainline alignment at about MP 321 and running within the railroad right-of-way at grade to the existing Greensburg station site. A single high-level island platform would be provided.

Greensburg - Pittsburgh

West of Greensburg, it is proposed that HSR would be built in the Conrail right-of-way. Trackage would be built to provide a two-track dedicated railroad (Tracks 2 and 3) with Conrail freight on Tracks 1 and 4 up to MP 346. Between MP 346 and

348, only three tracks would be provided, with at least one track shared between HSR and freight usage. At MP 348, it is proposed that Conrail freight would be diverted to the Brilliant Branch, which would be upgraded. From MP 348 to MP 353, the existing two tracks would be used only by HSR and remaining long-distance Amtrak service.

In many places between Greensburg and Wilkinsburg, facilities would probably have to be shifted to accommodate additional HSR trackage. It would also require additional right-of-way where the existing route is not wide enough or is unnecessarily speed-restrictive. Interlockings in this segment would be configured to provide cross-corridor access for local freight during HSR off-hours and for emergencies.

4.4.3 Discussion

Under Alternative D, ways were sought to improve trip time further and raise average speeds. Given the proposed routing, raising the maximum allowable speed to 180 mph would offer almost no improvement to trip time because of curves, grades and station stops. Virtually the only way to improve trip times substantially would be to reroute the line away from the cities which are proposed to be served directly. Bypassing downtown areas could save additional time; however, avoiding these downtowns would hurt ridership and would sacrifice potential urban development benefits. In Philadelphia, the option of extending service to the new Market East Station should be considered.

4.5 ALTERNATIVE E

The objectives of this alternative are the same as those of the foregoing HSR alignment alternative, except that by using Maglev technology, higher performance levels can be achieved. Maglev would negotiate steeper grades than HSR (up to 6 percent grades were assumed in this study, although the technology is capable of overcoming even steeper grades). This hill-climbing ability would permit the elimination of some tunneling and would minimize earthwork. Maglev acceleration and maximum speed are sufficiently high that route length becomes a secondary issue, and straightness of primary concern. Using a 12-degree guideway bank angle, with 3-inch unbalance at the design speed, horizontal curvature would have to be restricted to no more than 0 degrees, 20 minutes (a radius of 17,360 feet) to permit 250-mph operation. Guideway bank angle is limited by the effect on riders of stopping a train on a banked section of track. While a bank angle of 12 degrees would subject passengers to 0.21g steady state lateral acceleration when stopped in a curve, this angle was judged to be acceptable because of the projected infrequency of unplanned stops and the relatively mild, though noticeable, discomfort of this level of unbalance.

The proposed Alternative E route shown in Figure 4-1 is 313 miles long. A schematic plan of the route is provided in Figure 4-9. The following narrative provides a brief description of the physical aspects of the Maglev alignment from Philadelphia to Pittsburgh, by segment. Between Harrisburg and Greensburg, the alignment is identical to Alternative D.

This concept uses alternating stretches of single and double guideway connected by high-speed switches rather than full double guideway. This was done to help keep

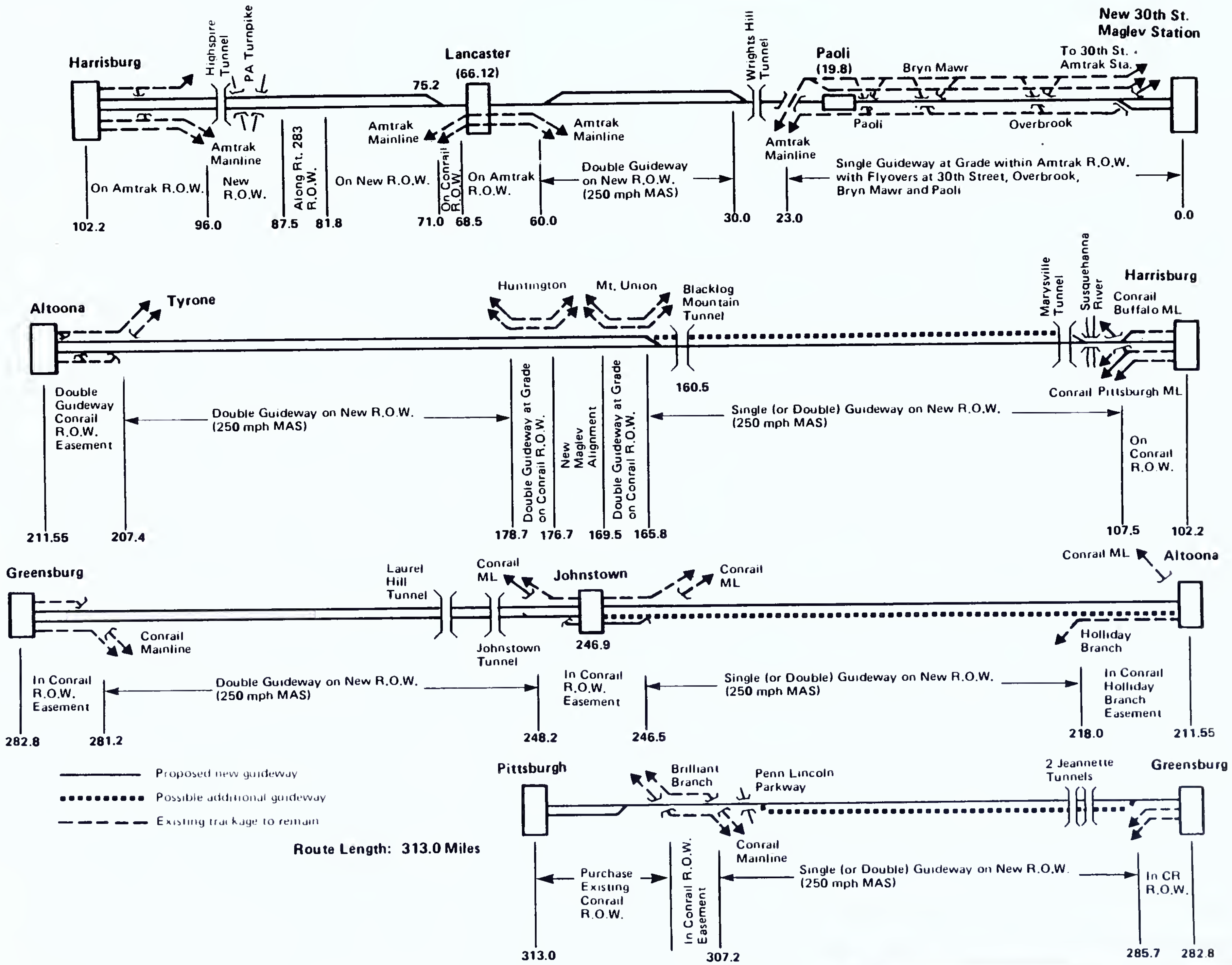


Figure 4-9
Alternative E
Schematic Plan

down the cost while still allowing at-least-hourly service in both directions. Using a single guideway in narrow rights-of-way, such as between Philadelphia 30th Street and Paoli, is not merely a matter of convenience or obtaining cost savings, however. There are no obvious ways to obtain a wide enough right-of-way for a double guideway in this corridor, and no other corridors between these two points are nearly as attractive as the existing one. Nevertheless, the use of a single guideway carries serious drawbacks, not the least of which is the inherent operational inflexibility and the inability to bypass a stalled train or guideway malfunction. Also, there are significant safety issues: the closing speed of opposing trains could approach 500 mph. Also, safety and reliability issues surround the operation of a high-speed guideway switch.

4.5.1 Alternative E — Segment Descriptions

Philadelphia - Lancaster

Between Philadelphia 30th Street (where a new Maglev station would be built just west of the existing Amtrak station) and Paoli, a single guideway would be built at grade in place of existing Track 2. The guideway would be elevated to fly over interlockings at Valley/Overbrook, Bryn Mawr and Paoli so that Amtrak, SEPTA, and Conrail could continue to enjoy operational flexibility.

At Paoli, a new platform would be required near the Route 30 underpass (Amtrak MP 20.52) just west of Paoli interlocking in three-track territory. At Malvern, the guideway would duck under the existing flyover and follow the abandoned Conrail branchline over U.S. Route 202 near Frame Avenue and then cross over Route 202 on a new bridge headed northwest. A single guideway is proposed to be built on a new alignment through Chester Valley, primarily at grade up to Wright's Hill (approx. MP 28). To avoid disrupting the community of North Valley Hills, a single guideway tunnel approximately 1.5 miles long would be required under Wright's Hill. At MP 30, a switch would be built and a double guideway section would begin.

Guideway would be built at grade, in cuts, or elevated as best suits the terrain heading west towards New Holland. Where crossing sensitive areas such as farmland, it was assumed that the guideway would be elevated on an easement, which would take as little land as possible and would permit continued use of the surrounding land for agriculture and other uses.

The double guideway would skirt north of New Holland and then turn south following a high-tension power line for several miles before entering the Amtrak right-of-way at about existing MP 62. Double guideway could be constructed at grade within the present right-of-way to the Lancaster station. Up to existing MP 65.5, site of the junction with the New Holland secondary track, there is room for a double guideway if existing Amtrak Track 2 is shifted closer to Track 1. West of there, only a two track right-of-way exists; however, it was assumed that only a single guideway would be needed, leaving a single-track railroad for local freight and remaining Amtrak service. A Maglev flyover would be required over Conrail's New Holland secondary track.

The north side of the station (existing westbound platform) could be reconstructed to serve Maglev trains. If needed, space would be available for a double-track guideway through the station, served by an island platform.

Lancaster - Harrisburg

The proposed alignment follows the existing Amtrak alignment west of Lancaster for 3 miles and then diverges to the northwest at Flory's Mill along the existing very lightly used Conrail branch line to Lancaster Junction. A single guideway is proposed up to MP 75. It could be constructed primarily at grade except at numerous highway crossings. A combination of underpasses and elevated guideway could offer the most economical way of providing grade separation.

West of MP 75, a double guideway would be required to accommodate passing trains between Lancaster and Harrisburg. The proposed route would be located on a new alignment through undeveloped land north of Mount Joy, then follow the Route 283 corridor running between the highway and the adjacent power line for about 5 miles, finally crossing over farmland and the Pennsylvania Turnpike northeast of Middletown. A short segment of cut-and-cover tunnel is proposed near Middletown High School to avoid long-term disruption to that facility. The line then would follow the turnpike, running almost due west to Highspire, where it would join the Amtrak right-of-way at about MP 91. The double guideway through Highspire would have to be depressed or placed in a tunnel to provide grade separation and mitigate as much as possible the environmental impact of building a new line through a residential area and commercial center.

The proposed new alignment could provide consistently high speed for its entire length from Lancaster Junction to Highspire.

Between Highspire and Harrisburg, the Maglev route follows the existing Amtrak/Conrail right-of-way, using a double-track guideway at grade, displacing one, or in some places, two existing railroad tracks. Existing rail service through the area would have to be preserved. In Harrisburg, a single island platform accessible from the existing Harrisburg Amtrak station would be built in place of an existing platform and two tracks.

Harrisburg - Altoona

The segment west of Harrisburg would require a single guideway on a new alignment that would diverge from the Conrail mainline right-of-way at Rockville on a flyover crossing over old Route 22-322 and the southern edge of Fort Hunter Park, and then would cross the Susquehanna River on a new bridge just upstream from the existing Rockville Bridge.

Upon reaching the western shore, the line would operate in a one-half mile cut-and-cover tunnel beneath downtown Marysville. Emerging just west of town, the line would run along the base of Cove Mountain, as under Alternative D, providing the capability of at least 230 mph operation up to Tuscarora Mountain, and then 205 mph operation from there to Mount Union. A tunnel would be required under Blacklog Mountain. A significant savings would result if only a single bidirectional guideway were required in this segment. (The Susquehanna River Bridge and cut-and-cover tunnel segments also would be much less costly using single rather than double guideway.)

The proposed line would cross the Juniata River about 2 miles southeast of Mount Union and remain elevated over Boro Line Road and onto the Conrail mainline right-of-way at about MP 189.3. It would then become a double guideway at grade through Mount Union on the Conrail right-of-way. As under Alternative D, the speed through Mount Union and Huntingdon would be restricted to 95 mph to avoid disruption. Between Mount Union and Altoona, the Maglev alignment follows the same route as Alternative D.

The Maglev station in Altoona could be built adjacent to the site of the existing Amtrak station which is being relocated to a new site along 10th Avenue. To avoid conflict with the existing Conrail junction, it would likely be elevated.

Altoona - Johnstown

South of the station, the line would follow the right-of-way of the lightly-used Holliday Branch which is mostly on embankment. A single guideway would suffice throughout this segment which could be built almost entirely within the right-of-way. Just north of Duncanville, the line would diverge from the Conrail branch and follow the new Route 220 alignment for about 2 miles, along side or in the median, space permitting. At about a mile south of the old Route 220/22 junction with Route 764, the Maglev line would diverge from the new highway alignment and flyover old Route 220 heading southwest on a new alignment toward Blue Knob. The line would pass through rural and forested areas north and west of Blue Knob, requiring cuts, fills, and aerial structures to cross ravines. Approaching Johnstown, the line would be built on an elevated structure to cross the Little Conemaugh River and Conrail mainline, coming down within the railroad right-of-way about 2.5 miles east of the Amtrak station. The Maglev station would be built at grade within the existing right-of-way adjacent to or as part of the Amtrak station.

Johnstown - Greensburg

The segment from Johnstown to Greensburg would be double guideway on mostly new alignment. The line would follow the Conrail alignment for roughly 0.5 mile to the northwest, crossing over the river and highway. Rising on a cut along the side of the Brownstown hill, the line would curve to the left continuing to rise and then pass through two 0.5- to 0.75-mile-long cut-and-cover tunnels to avoid deep open cuts west of Brownstown, avoiding what would otherwise be an eyesore to the community. The line would then continue west at grade up to Laurel Hill where a 0.75-mile-long tunnel would be required. From there, the alignment gently winds through the hills, skirting south of Derry, crossing over the Conrail mainline at Bradensville. The line approaches Greensburg form the northeast, joining the Conrail mainline alignment at about MP 321 and running within the railroad right-of-way at grade to the existing Greensburg station site. A new Maglev station with a single island platform at grade would be provided.

Greensburg - Pittsburgh

The segment between Greensburg and Pittsburgh would need to be only single guideway to accommodate hourly service. The line would diverge from the Conrail right-of-way about one mile west of the station and curve north through the outskirts of Jeannette and then head west through suburban areas that would require further study to identify an alignment with the least disruption to local development. Short tunnels at Jeannette and Claridge would probably be required. At Pleasant Valley, the line would cross over the Pennsylvania Turnpike and head northwest following the turnpike alignment at grade to the Monroeville interchange. The proposed line would then fly over the interchange and follow Route 22 (Penn Lincoln Parkway) west to Edgewood. It would closely follow the Parkway alignment, staying south of the roadway mostly on elevated structure. At Edgewood, the line would fly over the Parkway to join the Conrail right-of-way. From Wilkinsburg to Home Interlocking, the single guideway would share the right-of-way with two railroad tracks and the busway. It is proposed that Conrail freight operations be diverted at Home Interlocking to the Brilliant Branch, which would be upgraded, providing room for a single guideway at grade to run parallel with a single railroad track for Amtrak and local freight the rest of the way into downtown Pittsburgh. At the site of the existing Amtrak station, a new Maglev terminal would be built.

CHAPTER 5
EQUIPMENT REVIEW AND TRAIN PERFORMANCE

This chapter deals with vehicle technology available and/or under development worldwide that could be adopted for use in the Pennsylvania Corridor. The candidate train systems are first introduced; then issues related to their use in this application are discussed (Americanization issues); and finally, their characteristics, trip time and energy consumption characteristics are presented. Detailed descriptions are provided in Appendix A.

Since their invention 150 years ago, railroad passenger cars and locomotives have undergone steady, but generally gradual, improvement, as new materials became available and refinements were made. Recently, however, a tremendous acceleration in the pace of change has taken place. Although railroad equipment development is still, basically, an evolutionary process (the revolutionary change is coming in the form of Maglev), virtually every vehicle component and performance feature has been significantly improved in the last 25 years. Lightweight car bodies; high-speed, lightweight trucks (equipment assemblies consisting of wheels, axles, motors, gears, brakes and suspension systems); high-performance propulsion and control systems and many other sophisticated pieces of equipment have been incorporated in recent vehicle designs[1].

The most advanced technology has been developed in Europe and Japan. Currently, the highest-performance, most sophisticated passenger train in the world is the French TGV. The Japanese Series 961 prototype equipment is not far behind in terms of sophistication and performance.

With a market for their product and with strong support from their governments, European and Japanese equipment suppliers have innovated more than their American counterparts. U.S. firms have begun to license foreign designs to stay competitive. Amtrak's lightweight AEM-7 electric locomotives, for instance, built by General Motors under a license agreement with ASEA, a Swedish firm, incorporate many European design features.

European high-speed rail vehicles are typically lightweight, streamlined, and electrically powered. Their light weight minimizes horsepower and braking-effort requirements, wheel wear and track deterioration. Traction motors in Europe are normally carbody-mounted, rather than axle-hung, as in the U.S., to reduce unsprung mass (weight below the primary suspension system). Their running gear is designed for high speeds to avoid wheel climb (the wheel climbing the rail head) and hunting behavior (horizontal oscillation of the wheelset between the rails). Thyristor controls provide smooth application of electric traction power, and combinations of dynamic and friction (or hydrokinetic) braking systems provide effective deceleration from high speeds.

Marked differences separate U.S. and foreign designs. American equipment exemplifies durability and low maintenance--stainless steel carbodies; massive undercarriage and running gear; and rugged, heavy-duty traction equipment. European equipment, typically, has been lighter, less rugged, and designed for higher speeds; it also generally requires more periodic maintenance than American railroads are used to providing. European standards for international interchange service are specified by the Union Internationale des Chemins de Fer (UIC) in Paris. The UIC standards differ from the U.S. Code of Federal Regulations (CFR) standards administered by FRA. This can create a problem for assessing the acceptability of operating non-domestic-built trains in the United States. For example, the UIC's minimum required buff load, at 220 metric tons (440,000 lbs), is significantly less than the 800,000 lbs specified by the CFR. (Buff load is the compression load on the carbody structure, and is one measure of crashworthiness.)

The primary objectives for very-high-speed tracked vehicles are to provide sufficient propulsive force (tractive effort or linear motor thrust), to provide fail-safe braking, to reduce drag (rolling resistance and/or aerodynamic drag), and to keep vehicle weight and track forces to a minimum that is consistent with structural requirements and safety. Short travel times are important in providing competitive passenger services. High average speed is one key to shortening the intercity portion of a journey. High average trip speeds require equipment that has the power to climb gradients and to accelerate quickly after station stops or curve slowdowns. Such systems require a carefully integrated trainset operating over excellent track structure on a sound roadbed.

Varying operational requirements of the world's leading passenger railways have led to emphasis on different technologies. These needs vary from country to country because of factors such as terrain, traffic density, prevalent form of available energy, work rules, travel distances, and national transportation policy.

Examples of differing approaches are: construction of new, direct, high-speed alignments (e.g., France, Italy and Japan); the development of trainsets that could travel faster on existing, curved alignments (Canada, England, Italy, Sweden, and Switzerland); equipment that conserves energy by means of higher propulsive efficiencies (France, Germany, Japan, Switzerland); or the development of new high-speed vehicle technologies using magnetic levitation (Germany and Japan).

5.1 CANDIDATE TRAINS

A review of worldwide vehicle technology identified candidate trains for Alternatives C, C-Electric, D, and E, as discussed below.

5.1.1 Alternative C

The following trains are candidates for use under Alternative C:

- Canadian LRC
- British HST

Both are lightweight, diesel-electric trainsets designed for a top speed of 125 mph. The LRC, shown in Figure 5-1, is a tilt-body train. The HST, shown in Figure 5-2, is of conventional suspension.

Diesel traction offers freedom from the capital expense of electrification, but is uncompetitive in acceleration and top speed with trains operating from wayside power.

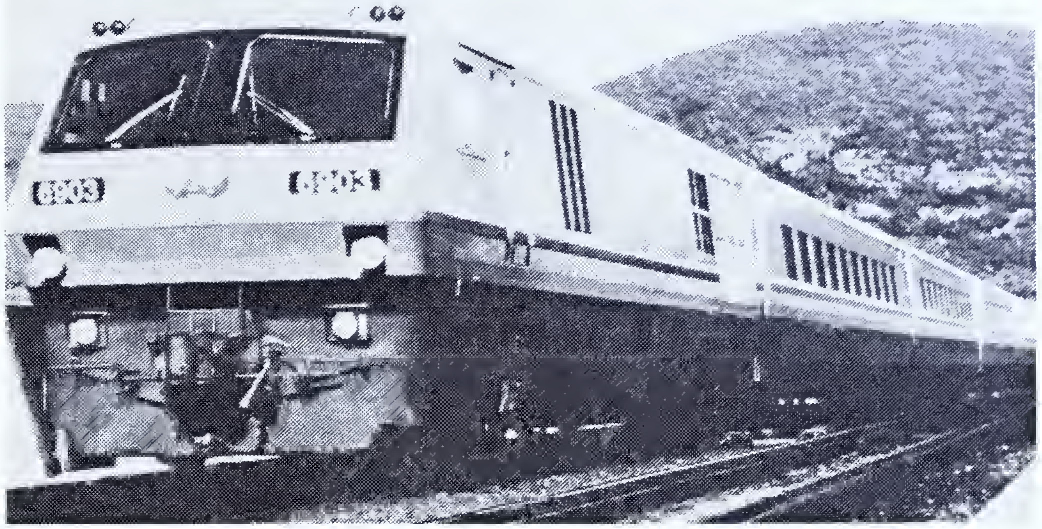


Figure 5-1
VIA Rail LRC Train

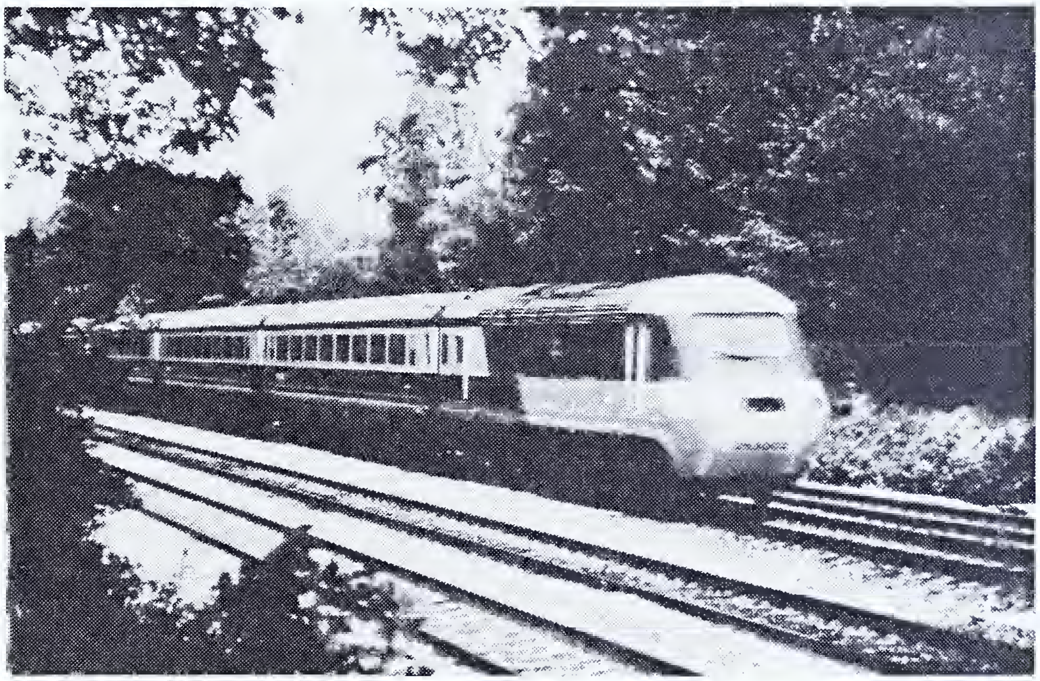


Figure 5-2
British Rail HST Train

If substantial route curvature is present, as in Alternative C, tilt-body equipment such as the LRC can negotiate curves at higher speeds than non-tilting trains such as the HST because of its low center of gravity and banking carbody feature, which raises the speed threshold of passenger discomfort in curves.

In this study, the reason the maximum speed under Alternative C is limited to the 110- to 120-mph range is because the number and severity of grades and curves precludes serious consideration of higher speeds.

5.1.2 Alternative C-Electric

The following trains are candidates for Alternative C-Electric:

- American AEM-7/Amfleet
- Canadian Electric LRC
- West German ET 402
- Italian ETR 401
- British APT

Metroliner Service on the Northeast Corridor is currently provided by an AEM-7 electric locomotive pulling Amfleet II passenger cars (Figure 5-3). The AEM-7, designed for both 25 kV/60 Hz and 11 kV/25 Hz, is capable of hauling 6 to 8 cars at 120 mph or more on level, tangent track.

Bombardier proposed a 150-mph, electrically-powered version of its LRC trainset for the second phase of its Florida High Speed Rail development program. The equipment would consist of electric locomotives, derivatives of an earlier LRC-E design, coupled to each end of an LRC coach consist in the same manner as the diesel-powered trainsets. The all-electric trainset is part of a product development program at Bombardier.

The ET402 is a very streamlined train designed for 125 mph operation. It is an electric multiple-unit train which operates on 15 kV, 16-2/3 Hz.

The ETR401 is a lightweight multiple-unit train designed for 155 mph operation over the "Direttisima" line under construction between Milan, Florence and Rome. It can also operate at relatively high speeds over reverse curves in mountain territory because of its carbody banking capability. It operates on 3,000 volts ac.

The APT was originally designed to operate over Great Britain's existing electrified railways at speeds up to 150 mph. The APT features carbody articulation for overall trainset lightness, as well as carbody banking for passenger comfort in curves. Development problems have slowed the implementation of the APT and have caused British Rail to proceed cautiously.[2]

Alternative C-Electric considers the use of electric, conventional and tilt-body vehicles on new track generally within the existing right-of-way at a top speed of 120 mph. Raising the maximum speed above 120 mph would reduce the trip time by only a few minutes because route curvature would restrict speed in most segments to less than the maximum.

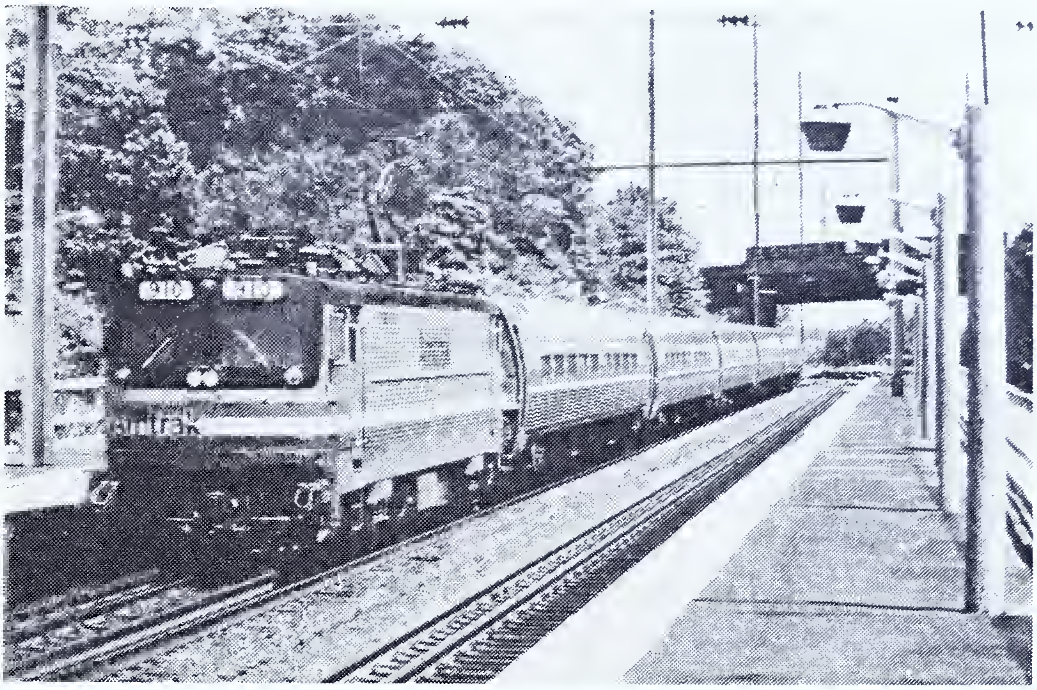


Figure 5-3
Amtrak AEM-7/Amfleet Train

5.1.3 Alternative D

Three trainset systems fit in this category: the French TGV, the Japanese Series 961, and the proposed German Intercity Experimental train (IC-E).

The TGV, shown in Figure 5-4, was designed as an integral part of a new rail system designed to operate at very high speeds on a new line between Paris and Lyon, and at conventional speeds on existing track elsewhere in the SNCF system and in neighboring countries. It has good adhesion and can start and accelerate on a 3.5 percent grade. The TGV, currently operating at speeds up to 168 mph, features an articulated design with eleven cars (including a power car on each end) permanently coupled. The train operates on 25 kV, 50 Hz and 1.5 kV dc. (Some trains also have 15 kV, 16-2/3 Hz capability.) The export version of the TGV intended for use in the United States would be a derivative of the TGV-Southeast now in SNCF service. This version, the TGV-Atlantique, is proposed to feature synchronous alternating-current traction motors in place of conventionally-wound direct-current traction motors.

The Series 200 Bullet Trains are now operating at speeds of 130 mph over the new Tohoku and Joetsu Shinkansen in the snow and mountain territories of Japan. Prototypes for the Series 200 were the Series 961 and 962 trainsets built in the late 1970s. The 961, shown in Figure 5-5, was tested to 198 mph; the 962 was designed for service in the 130- to 150-mph range. The Series 200, modeled more closely after the 962, is a lightweight train by most standards and is somewhat lighter and less powerful than the Series 961 prototype trains. The Series 200 incorporates little advanced technology but, like the TGV, represents adroit use of conventional components. All the equipment is designed for operation on 25 kV, 50 or 60 Hz electrification. For 160- to 180-mph operation, a train with a power rating and operating characteristics more like the Series 961 would be required. Of all the candidate trainsets, the Japanese equipment has the lowest collision strength, having been designed for only 220,000 lbs buff loading.

German Federal Railways began development of the IC-E express train in 1982. Prototype tests will begin in December 1985 with a 1-2-1 consist, leading to a 1-6-1 preproduction consist. The 186 mph (300 km/h) train is designed to provide 400 passenger seats and will be hauled by a 5,600-kW locomotive at each end in a push-pull arrangement. The locomotives will use E120 asynchronous propulsion technology.

5.1.4 Alternative E

Two different Maglev technologies are being developed: attraction or electromagnetic suspension (EMS) technology in West Germany, and repulsion or electrodynamic suspension (EDS) technology in Japan and Canada. The basic features of the two Maglev technologies are listed in the table below.

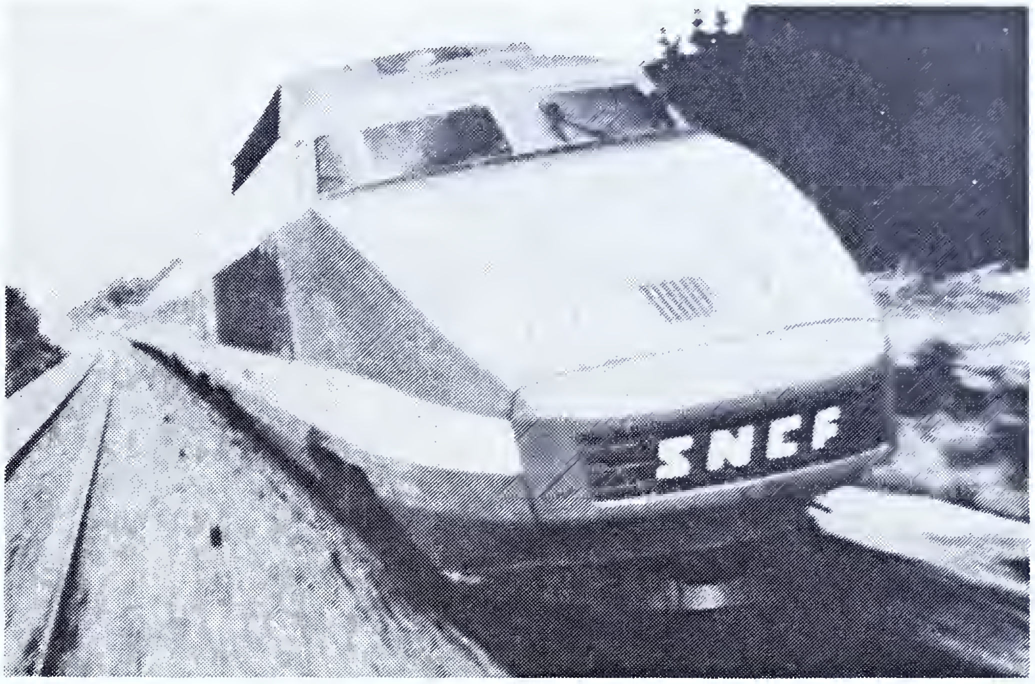


Figure 5-4
SNCF TGV Train

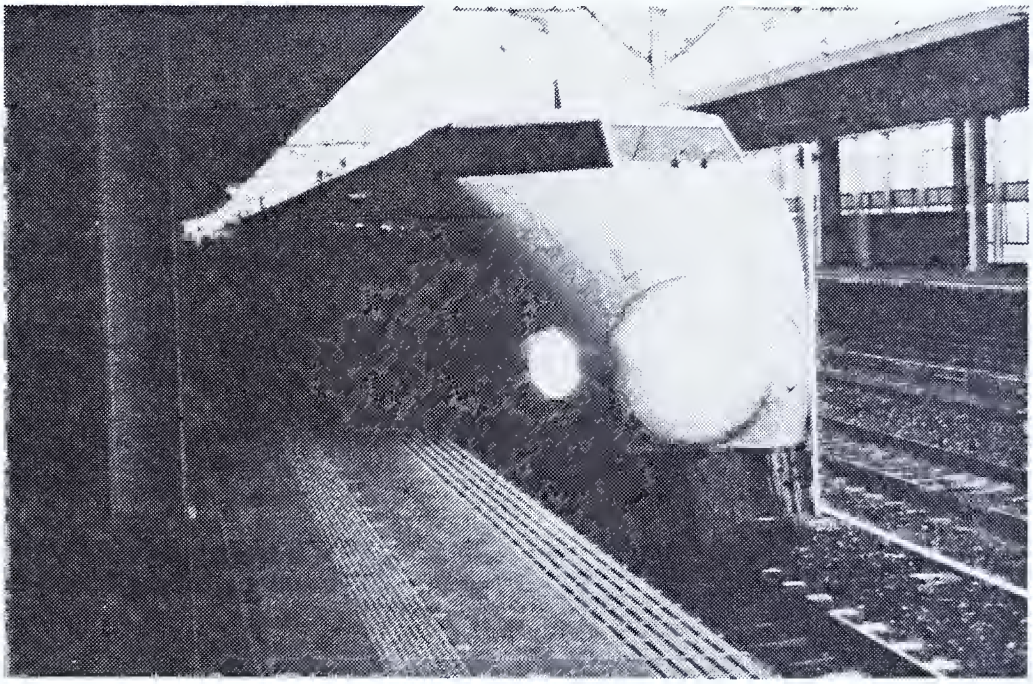


Figure 5-5
JNR Series 961

Feature	Attraction or Electromagnetic Suspension	Repulsion or Electrodynamic Suspension
Air Gap	1/2 inch	4 inches
Wheels	None (Skids)	Auxiliary wheels for support at low speeds (less than 50 mph)
Type of Magnet	Iron-Core Electromagnets	Superconducting Coils
Stable Levitation	Requires continuous electronic sensing of the gap and continuous control of the magnetic current	Requires reaching a sufficient forward velocity (about 50 mph)
Propulsion	Long-Stator Iron-Core Linear Synchronous Motor	Long-Stator Air-Core Linear Synchronous Motor

In Japan, research and development on EDS-type Maglev has been progressing since 1970. Test runs with a prototype car, ML-500, were begun at the Miyazaki Test Center in 1977. The test vehicle, shown in Figure 5-6, achieved a speed of 321 mph in December 1979 on a 4.35-mile test track with an inverted T-shaped guideway. Upon reaching this level of performance, the test track was converted to a U-shaped guideway, and a new test car, MLU-001, shown in Figure 5-7, was built. This car was designed to reduce cost, improve vehicle aerodynamic characteristics and make space available for passengers. Test runs on this reconfigured guideway started in 1980, and a two-car consist began test operation in 1981. Now the testing has reached the stage of a three-car test train able to carry passengers in the middle car (Figure 5-8).

The Canadian Transportation Development Centre has sponsored experimental work and system studies of repulsion Maglev. The Canadian Institute of Guided Ground Transport, CIGGT, in 1980 published a conceptual design of a revenue Maglev transportaion system for the Toronto-Ottawa-Montreal corridor.[3] Although superconducting magnets and linear synchronous motors are conceived as being used as in Japanese system, the guideway has no side walls, which simplifies switching and avoids snow accumulation problems which are more serious in Canada. The analyses have been innovative and first-rate but the level of funding has not permitted the creation of much Maglev hardware in Canada, nor is there any schedule for implementation of a revenue system.

The West German Maglev system is now at an advanced testing stage. Transrapid International, a consortium of West Germany companies led by Messerschmidt-Bolkow-Blohm (MBB), is responsible for testing its Maglev system at Emsland in northwest Germany. A test track of 19.6 miles has been constructed at the site, and the Transrapid 06 vehicle built by the consortium, shown in Figure 5-9, is undergoing trial runs. Tests are scheduled for completion in 1986. The project is being sponsored by the German Federal Ministry of Research and Technology. No definite plans exist regarding application of the Maglev system to commercial operation in Europe. This system has been proposed for the Las Vegas-Los Angeles and Chicago-Milwaukee corridors in the United States.

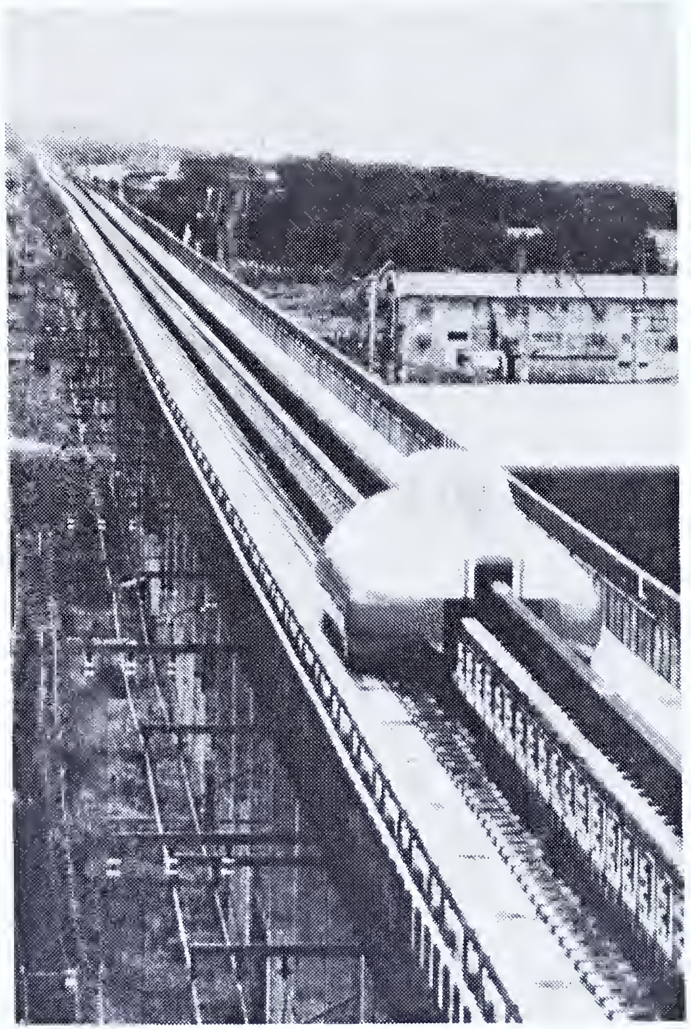


Figure 5-6
JNR ML-500
Maglev Test Car

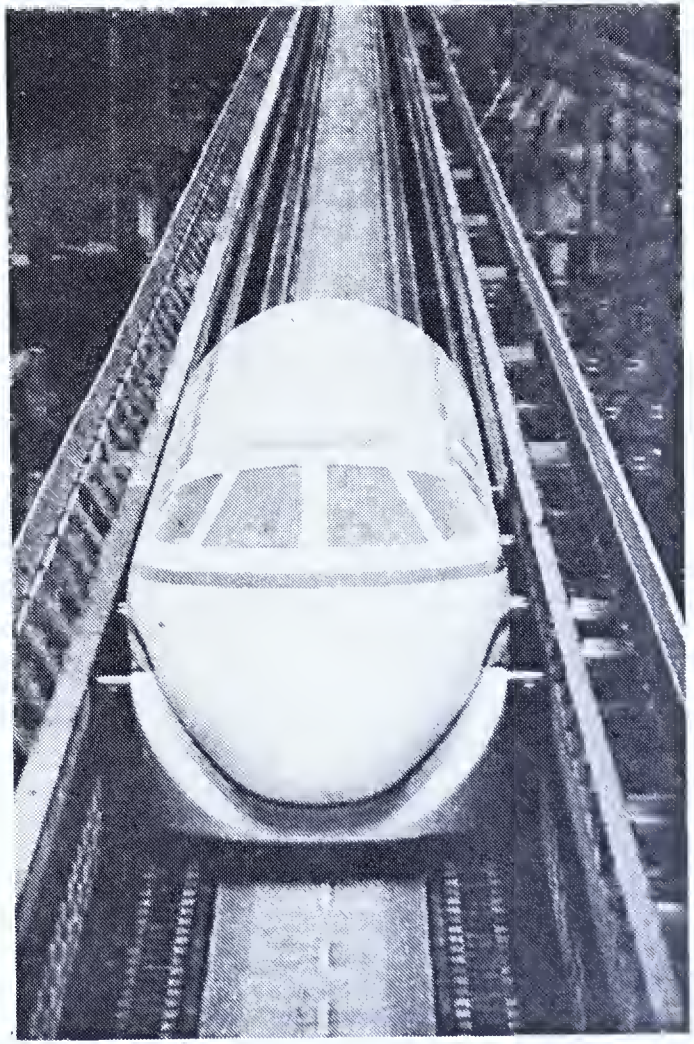


Figure 5-7
JNR MLU-001
Maglev Test Car

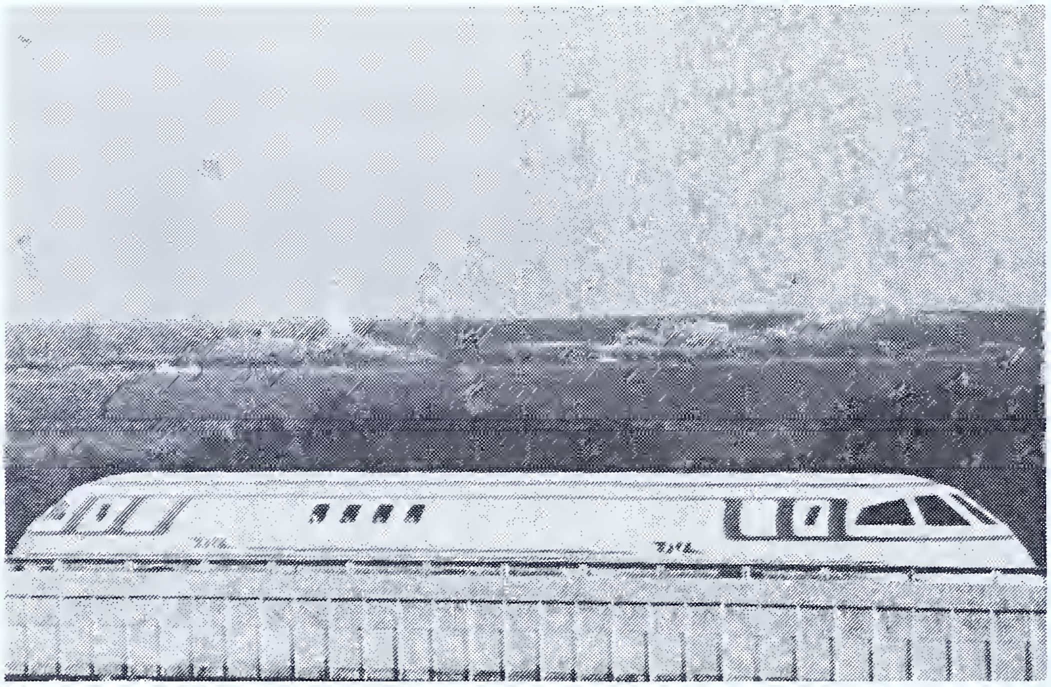


Figure 5-8
JNR Three-Car Maglev Test Train

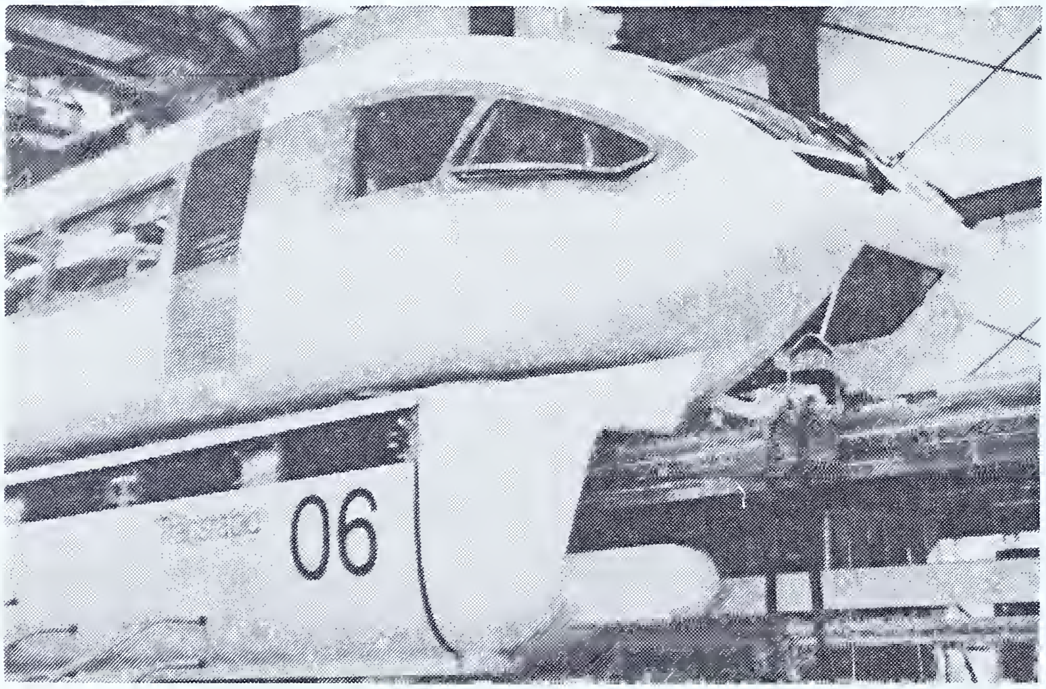


Figure 5-9
Transrapid 06 Maglev Test Train

5.2 AMERICANIZATION

"Americanization" of the structural design of foreign trainsets is an issue that may be dealt with in several ways to assure safety in high-speed train operations. One way is to meet certain structural requirements as stated in the CFR, which are enforced by FRA. Another way is to operate the equipment on completely grade-separated track dedicated to the exclusive use of the train in question. It is not the purpose of this analysis to attempt to resolve the various points of the issue, but to review the various trains proposed for high-speed operations within the constraints of existing structural requirement codes.

Effective January 1, 1984, the Association of American Railroads (AAR) cancelled its interchange rules for passenger cars and republished them as recommended industry practice. This action by AAR also applied to the brake system of passenger cars. In response, FRA took two actions: (1) amended its power brake rules to ensure continued inspection and testing of passenger car power brake systems, and (2) convened a Special Safety Inquiry in 1984 to explore the effect of technological changes in the passenger service industry, to assess the need for uniform standards for safety-critical components of passenger cars.[4]

Locomotives are still subject to FRA's Locomotive Safety Standards, as are self-propelled passenger cars (whether electric, diesel-electric, or turbine-driven). Self-propelled passenger vehicles are subject to the same minimum safety standards for their significant mechanical and structural components as required for passenger locomotives.

The rules address the condition of wheels and axles in terms of stress or fatigue cracking and wear; and set standards for brake, suspension, coupling and electrical systems as well as the crashworthiness of the car body. In addition, specific inspection and testing procedures are required. None of these items, other than crashworthiness, is addressed in this report.

There are five basic areas in which changes may be required for North American operation.[5] These are:

1. Structural reinforcements to meet CFR requirements
2. Propulsion equipment changes for use of dual voltage and frequency (11 kV, 25 Hz/25 kV, 60 Hz)
3. Modification of seating arrangement and specialty items such as cab signal systems
4. Adaptation of doors and steps for high- or low-level platforms
5. Modification of carbodies and/or trucks to meet clearance for restrictions imposed by existing corridor cross-sections.

Each of the trainsets under consideration represents an integral design capable of certain levels of performance. Adaptation to suit U.S. service operations, particularly the collision strength requirements and attendant weight increases, may completely disrupt the design integrity of the trainset. The adapted design could therefore represent a completely new version entailing considerable redesign cost and probably reduction in performance.

The first area, that of structural reinforcement, is of serious concern for all foreign locomotives, power cars, or self-propelled passenger cars built to the UIC buff strength requirements, as set forth in UIC Code 567-1 OR. These requirements represent approximately 55 percent of the AAR requirements. The additional strength and the weight of such changes could lead to a progression of other changes which affect the performance of the trainset design. These can be described as follows:

Progression of Weight Increases:

a. Primary (cause):
  - Collision strength reinforcement

b. Secondary (effects):
  - Increased propulsion equipment rating and weight to overcome weight increases
  - Increased brake equipment weight to overcome weight increases
  - Increased truck weight to handle weight increases

c. Impact of Weight Increases:
  Structural:
    - Additional support for increased size propulsion equipment
    - Additional support for increased size braking equipment
    - Additional truck load capacity
  Performance:
    - Additional tractive effort required to handle weight increases
    - Additional braking effort required to handle weight increases

The simplest approach is to increase the vehicle structural strength and accept a reduction in performance of the propulsion system brought about by the weight increase of the structure. Depending on the capacity of the trucks, this could be accomplished without a change in truck design. The friction brake capacity, however, would almost certainly have to be increased (or top train speed reduced) to handle the energy dissipation and deceleration rates required for signal stop distance.

5.2.1 Waiver Desirability and Feasibility

It would be desirable, from a cost standpoint, for a potential operator of a high-speed rail system to purchase and operate foreign equipment in structurally unmodified form; that is, to use the trains in the same structural configuration in which they are operated on their native railways. This might be feasible if it could be established that operational safety would not be jeopardized.

The safety records compiled by Japanese National Railways with its Shinkansen trains, and of French National Railways with its TGVs, are impressive. This requires a total commitment to safety that maintains safe train separation through operating procedures, communication and signal systems, and dedicated grade-separated tracks for each direction of travel for operation at speeds greater than 125 mph.

In the United States, the principal threats to passenger train safety, regardless of speed, are collisions with heavy freight-train equipment or highway vehicles. Slow, mixed traffic is common in the United States. Freight traffic in the vicinity of cities and industrial sites poses a threat to passenger train safety by virtue of the large mass of freight locomotives and cars, and the need for them to stop, start, or reverse direction while making deliveries to industrial sites along the right-of-way.

Designing a system with completely passenger-dedicated track may provide sufficient basis to obtain an equipment waiver on structural strength and other structural criteria. Using totally grade-separated private (non-interchange service) trackage, with adequate signal, communications, and control equipment, may offer a basis for waiving the 800,000-lb buff strength requirement in favor of an established UIC structural strength code. However, if the passenger equipment in question were to share any track with other common carriers, the waiver would not be applicable.

5.3 TRAIN PERFORMANCE

Various combinations of train consists and alignments were studied to arrive at performance estimates. The purpose of this analysis was not to recommend or select a train technology for the Pennsylvania Corridor, but rather to evaluate the influence of equipment characteristics on trip time and energy consumption for each combination.

The primary equipment factors of concern at this stage of the analysis were train weight, horsepower, tractive effort versus speed, train resistance and curve banking characteristics. Power density and vehicle cant deficiency (unbalanced elevation) were the principal vehicle characteristics that were varied. Selected candidate train parameters, typical of those used in determining the trip time performance of each alternative, are listed in Table 5-1. The tractive effort versus speed characteristics for each of these vehicles are shown in Figure 5-10.

For this study, a computerized train performance model (TPM) was used to determine the influence of route alignment and vehicle performance characteristics on energy consumption and trip time. The model can realistically predict the effect of grades, curves and other sources of speed restriction on train performance, given specific train resistance factors (weight, length and frontal area) and performance characteristics (horsepower, tractive effort versus speed, acceleration and braking rates, tilt capability, and so forth). The model has been calibrated and proven accurate.

5.3.1 Trip Time Estimates

A series of TPM calculations was made for each alternative. As incremental refinements were made to both the vehicle and route characteristics, new TPM calculations were performed. All TPM runs included either six or seven (in the case of Alternative D--State College) intermediate station stops with a 90-second dwell time for each. The dwell times were purposely kept longer than would be required for loading and unloading passengers to compensate for the fact that the raw TPM trip times do not include any operating "cushion". When timetables are prepared, a nominal amount of cushion (normally about 5 percent) is added to account for

TABLE 5-1

SELECTED TRAIN PARAMETERS[1]

Parameter	Alternative								
	A	B	C		C-Electric		D		E
Equipment Type	F40PH/ Amfleet	LRC	HST	Lightweight LRC	AEM7/ Amfleet	Electric LRC	TGV	961	TR-06
Proposed Base Case Train Consist	1-4	1-4	1-8-1	1-6-1	1-6	1-6-1	1-11-1	8	6
Train Weight (Tons) Fully Loaded *	350	350	395	560	430	500	640	605	375
Horsepower	3,000	2,700	4,500	7,000	7,000	12,000	8,650	11,800	13,200
Hp/Ton	8.5	7.7	11.4	12.5	16.3	24.0	13.5	19.5	35.2
Seating Capacity +	312	312	396	480	480	480	524	520	600
Assumes Maximum E_u (in)	4.5	9	4.5	9	4.5	9	4.5	4.5	3

* Weights of all foreign equipment include structural modifications thought to be required to meet U.S. requirements (Based on IPEEP).

+ Seating capacity based on Amfleet seating density for all but the TR-06 (Maglev) vehicle.

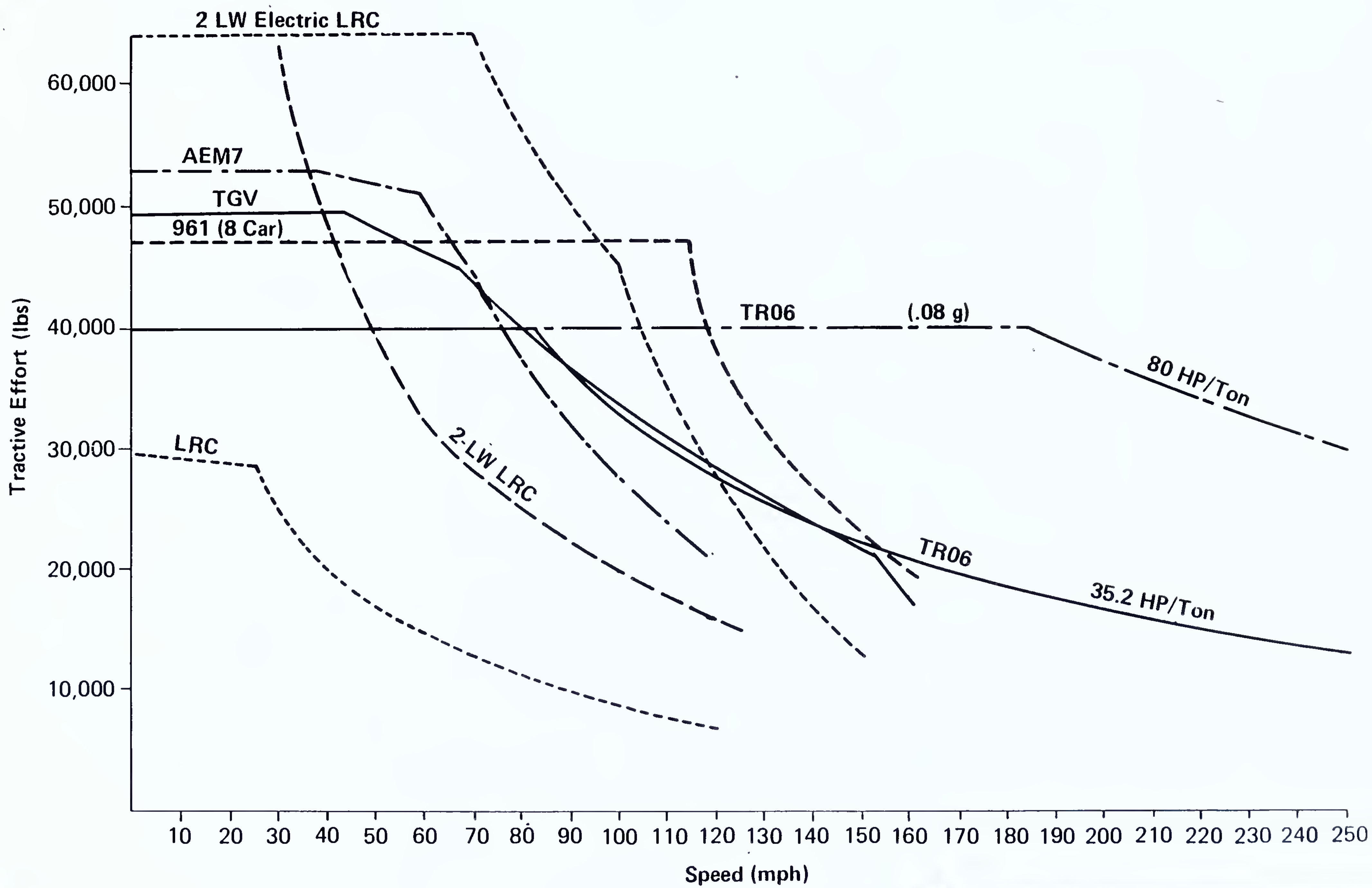


Figure 5-10
Tractive Effort vs. Speed Characteristics for Selected Vehicles

unscheduled delays such as traffic interference, equipment malfunctions, switch or signal delays, differences in operators' train handling, and so forth. In this study, cushion was not applied except as inherent in the 90-second dwell time at each station.

Table 5-2 provides a summary of typical trip time estimates between station stops and total times for each alternative. Route lengths and average running speed between stops are also shown.

These estimated trip times do not necessarily reflect optimum levels of improvement. They are strictly a function of the base-case level of improvement for each alternative as reflected in the cost estimates. There will undoubtedly be locations within each route alternative where the assumed speed limit cannot be practically achieved. On the other hand, there will also probably be segments where the speed could be raised even higher cost-effectively. Generally, however, the faster the speed the more expensive the level of improvement must be. In reality, there are innumerable refinements that could be made within each alternative which affect trip time. Only after a basic alternative is selected would it be worthwhile to study the detailed tradeoffs required to formulate a final detailed alignment and improvement plan.

5.3.2 Trip Time Sensitivities

The trip times shown in Table 5-2 reflect specific assumptions about route characteristics (primarily length, grade and curvature) and equipment performance. A function of geography and terrain, route characteristics cannot be changed readily without considerable investment in infrastructure improvements. Equipment performance is also a function of monetary outlay. Up to a point, trip time savings can be achieved most economically by increasing train performance (acceleration rate, speed capability in curves, maximum speed and braking rates), but wayside improvements must also be made to support higher speeds. Passenger comfort, rather than safety, almost always determines the practical limits of train performance. Nevertheless, significant tradeoffs exist in determining optimum train performance characteristcs once a route alignment has been selected.

Following are some preliminary trade-offs considered in search of ways to improve trip time and in assessing possible negative effects of less robust train performance under each alternative:

- Alternative C
  - The effect of unbalanced elevation (cant deficiency) on trip time is substantial. In fact, for Alternative C, it is estimated that the difference in trip time between operating conventional equipment at 4.5 inches of unbalance and tilt-body equipment (of the same power rating) at 9 inches of unbalance is about 20 minutes.

TABLE 5–2

TYPICAL TRIP TIMES6

	ALTERNATIVE																	
	A			B			C			C-Electric			D			E		
	LENGTH (MILES)	TIME (MIN)	AVG RUN SPEED (MPH)	LENGTH (MILES)	TIME (MIN)	AVG RUN SPEED (MPH)	LENGTH (MILES)	TIME (MIN)	AVG RUN SPEED (MPH)	LENGTH (MILES)	TIME (MIN)	AVG RUN SPEED (MPH)	LENGTH (MILES)	TIME (MIN)	AVG RUN SPEED (MPH)	LENGTH (MILES)	TIME (MIN)	AVG RUN SPEED (MPH)
Philadelphia																		
	19.0	**23**	52	19.0	**19**	64	19.0	**19**	67	19.0	**18**	71	19.0	**19**	65	19.5	**16**	80
Paoli																		
	48.0	**40**	74	48.0	**35**	88	47.9	**31**	98	47.9	**30**	100	47.9	**30**	100	46.5	**19**	160
Lancaster																		
	37.0	**32**	74	37.0	**27**	86	36.4	**23**	100	36.4	**23**	102	36.4	**24**	99	36.1	**16**	153
Harrisburg																		
	131.3	**145**	55	131.3	**107**	75	125.4	**79**	98	125.4	**76**	101	109.4	**55**	120	109.4	**53**	130
Altoona																		
	38.1	**58**	41	38.1	**41**	60	35.4	**29**	76	35.4	**27**	82	35.3	**21**	107	35.3	**17**	133
Johnstown																		
	48.0	**52**	57	48.0	**39**	77	45.5	**32**	91	45.5	**31**	94	35.7	**21**	110	35.7	**16**	145
Greensburg																		
	30.6	**40**	45	30.6	**29**	62	30.6	**25**	74	30.6	**25**	76	30.6	**26**	70	30.4	**19**	98
Pittsburgh																		
Total Route	352.0	**390** (6:30)	54	352.0	**297** (4:57)	71	340.1	**238** (3:58)	86	340.1	**230** (3:50)	89	314.3	**196** (3:16)	95	312.9	**156** (2:36)	120

NOTE: Times include 90 sec dwell at all intermediate station stops.

- Similarly, the power-to-weight ratio of equipment operated over the Alternative C route has a significant effect on travel time. Doubling the power density from about 15.5 to 31 hp/ton (presumably by means of electrification) would save about 8.5 minutes, end-to-end. Stated another way, changing the consist of a four-car/two-locomotive train would shorten trip time by about 2.5 minutes for each car subtracted.

- Raising top speed from 110 to 120 mph would save about 4 minutes of trip time.

- Eliminating the proposed route realignments (but still realigning individual curves within these route segments) would add about 12 minutes to the scheduled run.

- Adopting six additional route realignments in areas other than those discussed in the foregoing chapter would save about 7 additional minutes, but at considerable expense.

- Skipping intermediate station stops would save on the order of 2 to 3 minutes each.

- Rerouting the alignment via State College would save about 7 minutes, even considering the added station stop. This option would, however, involve considerable expense.

o Alternative D

- Cant deficiencies higher than 10.5 inches were not investigated under Alternative D, but probably would not produce trip time savings as dramatic as in Alternative C, because much of the route would be on a new, straighter alignment. The potential savings would be on the order of 5 to 10 minutes.

- Power-to-weight ratio is a very important factor influencing trip time under this alternative. While its influence has not been rigorously quantified, reductions in horsepower/ton associated with adding cars to a locomotive-hauled consist could make a substantial difference in end-to-end trip time, estimated as on the order of 3 to 4 minutes per added car. It would be important to determine an optimum power-to-weight ratio in specifying the motive power under this alternative. (Electric MU consists, of course, could be varied without affecting performance.) The base-case Alternative D alignment as currently conceived would require a train power level of about 20 hp/ton to achieve the proposed 3 hour, 16 minute schedule.

- Raising the top speed of the base-case alignment from 160 to 180 mph would cut the end-to-end trip time by less than 1 minute. This is because, at this speed, virtually the entire route would be restricted by curvature. Tangents between curves would generally permit 180-mph operation, but in most cases, they would be too short to sustain this high speed. An even straighter alignment, higher superelevation, or higher cant deficiency would be required to permit capitalizing on a 180-mph maximum speed.

  - A number of alternative route alignments were investigated in a preliminary fashion to arrive at the base-case alignment. Most of the earlier alignments were shorter and faster but were either environmentally troublesome or did not serve all intermediate downtown stops directly. The effects of these major route revisions on trip time are outlined below:

    - Use of existing right-of-way between Paoli and Harrisburg in lieu of originally proposed new alignment (+5 minutes)

    - Stop in downtown Altoona via Tyrone in lieu of Hollidaysburg (+9 minutes)

    - Use of Conrail right-of-way between Greensburg and Pittsburgh in lieu of originally proposed new alignment (+6 minutes)

  - Skipping intermediate station stops would save on the order of 3 to 4 minutes each.

  - Rerouting via State College, with an additional station stop there, would increase the trip time about 10 to 12 minutes over the base case. This routing would add about 5 miles in length and would follow the existing Conrail alignment for about 30 miles more than the base case.

- Alternative E

  - Cant deficiencies higher than 3 inches over and above the 12-degree bank angle were not investigated, but could provide marginal improvements in trip time. Time savings on the order of 2 minutes per inch of additional unbalanced elevation are estimated.

  - The power-to-weight ratio has a measurable effect on system performance. Raising the motor thrust from 13,200 lbs to 30,000 lbs would save more than 6 minutes end-to-end.

  - Relaxing the comfort criteria could have a minor effect on trip time. For example, raising the maximum vehicle acceleration rate from 0.08g to 0.1g would save about 1 minute overall.

  - An alternate alignment near Lancaster was investigated. About 2.5 minutes could be saved by serving a suburban station site instead of the existing Amtrak station.

5.3.3 Energy Consumption Estimates

The TPM also was used to estimate energy consumption rates for each alternative. Fuel or electricity consumed to operate a train is a function of its weight, route terrain, speed-vs.-distance characteristics of the equipment and the route, and the energy conversion efficiency of the equipment. Energy requirements were estimated for each vehicle at the point of delivery in each case, i.e., at the fuel tank for a diesel locomotive and at the pantograph for electrified vehicles. (This ignores spillage and evaporation in the case of diesel power, and generation, substation and transmission line losses for electric traction.) For Maglev vehicles, a 40 percent energy conversion efficiency was assumed, measured between the substation and the end use (levitation, propulsion or hotel power). This is to account for the relatively poor efficiency associated with the large motor air gaps required for this mode. Few actual energy consumption rates have been published for Maglev, making it difficult to check the validity of this estimate. Energy consumption rates for all other train systems are comparable with published data.

The energy estimates for the Pennsylvania corridor, in terms of British thermal units (btu) per trip and per seat-mile, are given in Table 5-3. On a train-mile or seat-mile basis, they are generally higher than one might expect for two reasons. First, the Pennsylvania Corridor has extremely demanding terrain -- steep hills, sharp curves, and numerous speed changes, requiring many train accelerations or decelerations. Second, in order to achieve short trip times, trains in the Pennsylvania Corridor must possess a relatively high power-to-weight ratio, requiring two locomotives in most cases to achieve the desired performance. This high power level adds weight and, therefore, increases the energy requirements.

It can be concluded that on the basis of energy consumption alone, no alternative is significantly better or worse than another. As performance goes up, so does energy consumption. Energy consumption figures for the diesel alternative are disproportionately higher because total energy conversion losses are included in the numbers shown (including diesel engine losses), whereas, under the electrified alternatives, only on-board conversion losses are included. If measured at the power generation source, the total consumption rates would be more nearly equivalent.

References

1 Virtually all of the rail vehicle data in this chapter are from J.A. Bachman, et al., Improved Passenger Equipment Evaluation Program (IPEEP), Volumes 1-9, prepared for Federal Railroad Administration, Washington, 1978-1979.

2 Railway Gazette International, July 1984.

3 R.W. Lake, et al., "Alternatives to Air: A Feasible Concept for the Toronto-Ottawa-Montreal Corridor," CIGGT, Queen's University, Kingston, Ontario, 1980.

4 "Railroad Passenger Equipment Safety," A Report to Congress by the Office of Safety, Federal Railroad Administration, January 1984.

5 "Methodology Used in the Train Reviews," IPEEP, Federal Railroad Administration, March 1979. (Available from U.S. National Technical Information Service (NTIS), Springfield, Va., PB80161763.)

6 Typical trip times shown are based on the following train consists: A--1-4 (F40PH - Amfleet); B--1-4 (LRC); C--1-4-1 (lightweight LRC); C-Electric--1-4-1 (lightweight electric LRC); D--1-7-1 (TGV); E--6 (TR-06).

TABLE 5-3

ENERGY CONSUMPTION ESTIMATES

	btu/trip* (millions)	btu/ seat mile*	Kilowatt-hours or gallons per trip
ALTERNATIVE C			
1-4-1 lightweight LRC diesel	82.7	784	584 gallons
1-4-1 electric LRC	29.4	279+	9,063 kWh
1-4 AEM-7/Amfleet	31.1	296+	9,100 kWh
ALTERNATIVE D			
1-7-1 TGV trainset	49.0	503+	14,368 kWh
ALTERNATIVE E			
4 car TR-06 Maglev train	73.0	596 +	21,410 kWh

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* btu measured at the fuel tank for diesel locomotives and at the power pick-up for other vehicles.

+ If measured at the fuel source, these figures would be more than 3 times the amount shown to account for power generation losses.

CHAPTER 6
HSR SERVICE CONCEPT

This chapter describes the required service implied by each HSR concept. These include train service frequency, fleet size, train supervision and operating concepts, vehicle inspection and servicing requirements, marketing, and passenger accommodations. Also, potential outside (non-transportation) sources of revenue are identified.

6.1 HSR TRAIN SERVICE

Implementation of Alternatives C, D, or E would involve establishing a new HSR operating entity or entities to plan, design, construct, and operate high-speed passenger rail service in the Philadelphia-Pittsburgh corridor. As now envisioned, this service would replace rather than compete with existing cross-state Amtrak rail passenger service. This implies a mix of high-speed intercity rail service and intermediate-speed commuter service between the major metropolitan areas.

In order to present a new, high-quality service alternative to the traveling public, high-speed intercity service is proposed to be provided hourly between Philadelphia, Paoli, Lancaster, Harrisburg, Altoona, Johnstown, Greensburg and Pittsburgh. Market conditions would dictate frequency of service, hours of operation, station stop patterns, train consists, and so forth. It is quite likely that more-frequent-than-hourly service would be offered at the peak morning and evening travel times, and less-frequent-than-hourly service would be provided in off-peak hours. Express service, with some trains not making all intermediate stops, might be offered in the peak hours.

Each of the alternatives (C, D, and E) was planned and costs were estimated for a pattern of hourly service from each endpoint between 6 am and 11:30 pm daily.

Travel characteristics of the Pennsylvania corridor have not been determined in enough detail yet to permit preparation of an operating timetable. However, line and station capacity and vehicle fleet sizes have been formulated with sufficient breadth to allow a considerable amount of freedom in train scheduling under each alternative. As transportation requirements are better defined, more detailed service plans can be developed.

Commuter service could be provided under Alternatives C and D by adding more stops to certain high-speed intercity trains in the peak hours, by operating additional (slower) commuter trains making more frequent stops, or by a combination of the two methods. Because Maglev technology is not conducive to slow-speed or frequent-stop operation, conventional commuter trains serving the intermediate communities (similar to the existing Amtrak Keystone service east of Harrisburg) might continue to operate alongside high-speed Maglev service under Alternative E. This slower-speed service might continue to be operated by Amtrak.

Non-commuter service to smaller intermediate communities west of Harrisburg, such as Lewistown and Huntingdon, would continue to be provided by Amtrak's long-distance trains, and these communities might also be served on a skipstop basis by non-peak-hour HSR trains. A marketing study would determine the frequency of service warranted by potential ridership from these communities. In designing HSR systems, a balance must be struck between the frequency of station stops and the average line speed that can be achieved. Obviously, the more stops, the lower the average speed, which tends to make HSR less competitive with other modes. On the other hand, very fast trains with few intermediate stops may not serve a large enough market to make them viable. The optimum balance among train speed, frequency and station stop pattern would have to be determined using market surveys and operating experience.

6.2 FLEET SIZE

The following minimum number of trainsets are needed to provide hourly high-speed service:

- Alternative C: Assuming 4-hour trip times, 1.5-hour train turns, staggered starts (i.e., departures on the hour from one end and on the half-hour from the other), one spare train at each end for protection of the next scheduled departure, and 20 percent unavailability (shop margin), a total of 16 trainsets would be required. This would permit operating at least 28 trains per day between the hours of 6 am and 11:30 pm.

- Alternative D: Assuming 3.25-hour trip times, 1.75-hour train turns, hourly departures from both ends, one spare train at each end for protection of the next scheduled departure, and 20 percent spares, a total of 14 trainsets would be required. This would permit operating at least 30 trains per day between the hours of 6 am and 11:15 pm.

- Alternative E: Assuming 2.5-hour trip times, 1.5-hour train turns, hourly departures from both ends, one spare train at each end for protection of the next scheduled departure, and 20 percent spares, a total of 12 trainsets would be required. (Staggered starts with 1-hour turns could reduce this to 11 trainsets, but 12 were assumed to be required for cost estimating purposes.) This would permit operating 32 trains per day between the hours of 6 am and 11:30 pm.

Train lengths will be dictated by ridership. Target load factors of between 50 and 60 percent were used in calculating the number of seat-miles required (based on the number of passenger-miles estimated for each alternative). Train lengths and overall number of vehicles required are shown below:

- Alternative C: Based on a projected travel demand of 240 passenger-miles per train-mile (pm/tm) and an average 50 percent load factor, each train must carry an average of 480 seats. Six Amfleet-type cars or six LRC-type cars (five coaches plus one cafe car) meet this capacity. To provide the horsepower per ton required for a 4-hour trip time under this alternative, two medium-horsepower or one high-horsepower locomotive would be required. For the purposes of the estimate, use of two medium-horsepower locomotives per trainset was assumed. This results in a fleet of 96 cars and 32 locomotives for a total of 128 vehicles.

- Alternative D: Based on a projected travel demand of 292 pm/tm and an average load factor of 55 percent, each train needs an average of 524 seats. Eleven TGV-type coaches with "Americanized" seating (or eight Series 961 MUs) would be required per train. This results in a fleet size of 14 11-car/two-locomotive, TGV-type trainsets or 112 Series 961-type EMU cars.

- Alternative E: Based on a projected travel demand of 340 pm/tm and an average load factor of 60 percent, each train must carry an average of 566 seats. It was assumed that six-car Maglev trains could provide this seating density, resulting in a fleet of 72 Maglev vehicles.

6.3 TRAIN SUPERVISION AND OPERATION

Train dispatching and supervision requirements will be determined by the number of trains and type of system to be operated. Under Alternatives C and D, account must be taken of possible shared use of some existing upgraded facilities, particularly track in and around stations. While shared use of facilities should be minimized to simplify train dispatching and operations, it may be necessary or desirable to work out joint operating and/or maintenance agreements or trackage rights for HSR trains to operate over portions of the existing route. No detailed consideration of train control and operations can be developed until a determination is made as to what facilities would be shared with Conrail, Amtrak and/or SEPTA. It is recognized, however, that wherever different services (i.e., HSR, Conrail, Amtrak and SEPTA) share a common right-of-way, safety features must be provided for all operators in the event of a mishap on one system to stop trains on the others. It is desirable to dispatch and control all HSR trains over the entire route from a central facility. The feasibility of this scheme, however, depends on the final system configuration, and particularly on how separate the HSR facilities are from others in the corridor.

Under Alternative E, unquestionably, operations would be controlled solely by the new high-speed operating entity. Trains would be dispatched and controlled from a central facility staffed with a dispatcher and train directors. In addition, supervisory operating personnel would be located in the field. Traction power and guideway switches would be similarly monitored and controlled centrally, with field maintainers on call to handle system failures and perform scheduled maintenance.

The size of on-board train crews would vary with train length and seating capacity. At a minimum, a train operator, a conductor and one or two additional personnel would be needed. Longer trains would require additional staff. On-board food service would also entail at least one attendant per train. Crews would normally work no more than four 10-hour shifts per week, and additional crews would be needed to cover the full 15- to 18-hour operating day and to make up for crew days off, vacation, holidays and sick leave.

6.4 VEHICLE INSPECTION AND SERVICING REQUIREMENTS

Car cleaners and inspectors would be needed at each terminal to "turn" the equipment. Trains might not literally be turned around, but the seats might be turned, and, in any event, time is required for cleaning and restocking the coaches and food service car and for inspecting the train running gear. Trip turns and inspections would be routinely handled in the terminal station to minimize hostling and maximize equipment utilization. Unscheduled repairs and thorough daily inspections would be performed in the maintenance-of-equipment (MOE) facilities (running repair facilities) adjacent to the terminals. Train exteriors would be washed and interiors thoroughly cleaned as part of the overnight inspection and servicing. Monthly inspections and major repairs would be performed in a separate heavy repair facility. Periodic maintenance would be planned to minimize equipment downtime. Specific MOE shop requirements were developed for each alternative based on fleet size and equipment propulsion characteristics, e.g., diesel-, electric-, or linear motor-powered.

6.5 MARKETING

Various levels of service should be considered in order to segment the market. An all-reserved premium service would cater primarily to the business traveler. Other forms of reserved service may also be considered. Unreserved coach, commutation, and excursion fares would target other market segments. A central information and reservation office would be needed to implement this type of service.

Tickets would be sold both directly and through travel agents. The agents would be paid a commission based on the value of the ticket sold. Direct ticketing would require printers at each station and perhaps at other urban ticket offices. Supplementary use of self-service ticketing should be investigated, but would likely involve only a small portion of the total sales.

It is assumed that advertising and promotion would be handled by an outside advertising agency. (An advertising budget of 3.5 percent of revenues was figured in the calculation of net revenues.)

6.6 FOOD AND STATION SERVICES

Train food service would be provided, probably on a contracted basis to the lowest bidder. Nowhere in the world does on-board food service recover its full costs. (A deduction from passenger revenues was included in the calculations to cover the shortfall of direct revenue against food service costs.)

Provision for passenger luggage must be made, both for carry-on and checked baggage. Redcap service would be offered at each station. In addition, a separate parcel service might be started as an attractive source of additional revenue.

Station attendants will be needed to provide passenger information, to offer assistance to handicapped travelers, and to serve as platform ushers at larger stations. All station facilities should be built or remodeled to accommodate wheelchair access to trains. Use of high-level platforms throughout is essential for short dwell times. Station signing and train information and announcement systems also would be required systemwide.

Station supervision would be provided by a general supervisor or stationmaster at each location on a two-shift basis. Security would be provided around the clock, either on a contracted basis or with HSR security forces. Closed-circuit television and other surveillance and alarm systems also would be required, at least at the major stations. All these accommodations are reflected in the projection of costs and revenues discussed in Chapters 8 and 10 respectively.

CHAPTER 7
INFRASTRUCTURE REQUIREMENTS

Prior chapters have described candidate technologies and corresponding alignment choices. Every combination involves a unique supporting infrastructure, requiring either upgrading of existing facilities or construction of new facilities. Components common to all alternatives include:

- Track/guideway and structures
- Grade crossing eliminations and fencing
- Electrification
- Communications and signaling
- Stations
- Maintenance facilities.

Each of these components is discussed separately in this chapter with reference to the requirements of Alternatives B, C, C-Electric, D, and E. Table 7-1 summarizes the system component characteristics under each alternative.

It should be noted that the infrastructure requirements are based on a general assessment of operating requirements (as discussed in Chapter 6) in each route segment. In some route segments, under some alternatives, joint operations are required and facilities have been projected to permit such operations. Specific facilities of this type include rail underpasses, additional interlocking facilities, track-center widening, right-of-way acquisition, cuts, and fills. The physical plant concepts proposed have not been endorsed by Amtrak, Conrail, or SEPTA, the three operators of the existing right-of-way. Further investigation of the physical and operational requirements of the selected alternative will be made in Phase 2. This investigation will include discussions with all appropriate owners and operators.

7.1 TRACK/GUIDEWAY AND STRUCTURES

The track or guideway's primary function is to support and laterally restrain train loads by distributing the pressure from the rail or beam to the ground at a level which the earth underneath can sustain under all weather conditions without settling. High-speed train operation requires that track be built and maintained to much more demanding specifications and closer tolerances than conventional, lower-speed track. Continuous welded rail, concrete ties, and sophisticated track-laying and maintenance equipment have been developed to improve ride quality, stability, and track safety, permitting speeds of 180 mph or more.

Track structure design has steadily evolved in the United States and abroad. Recently much money has been spent in the United States to develop and test improved designs, incorporating new materials and redesigned track components. The Facility for Accelerated Service Testing (FAST) track, in Pueblo, Colorado, has been the site of much of this work. The NECIP benefited from many of these recent domestic improvements in track design and construction.

To maintain very close tolerances, the Japanese have adopted a direct-fixation, "slab-track" design on the newer Shinkansen lines. Under this concept, the rail is solidly bolted through elastomeric rail fasteners to a concrete slab, constructed and

TABLE 7-1

INFRASTRUCTURE COMPONENT SUMMARY BY ALTERNATIVE

Item	Alternative				
	B	C	C-Electric	D	E
Track	Upgraded existing	Upgraded existing 2 tracks (Philadelphia-Harrisburg) 1.5 new tracks (Harrisburg-Pittsburgh) (wood ties)		Entirely new double (concrete tie) track	New guideway
Maximum Track Super-elevation/Guideway Bank Angle	Existing	6"		6"	12°
Maximum Grade	Existing	3 percent		3.5 percent	6 percent
Maximum Speed (mph)	110 Philadelphia-Harrisburg 90 Harrisburg-Pittsburgh	110-120		160-180	250
Grade Crossings	Existing with protection	Eliminated where feasible		100% eliminated	100% eliminated
Fencing	Existing (minimal)	10% of ROW	10% of ROW & OH Bridge	100% at-grade ROW & OH Bridge	100% at-grade ROW & OH Bridge
Electrification	Not used	Not used	Upgraded: Philadelphia-Harrisburg New: Harrisburg-Pittsburgh	Upgraded: Philadelphia-Harrisburg New: Harrisburg-Pittsburgh	All new
Communications & Signals	Upgraded existing	Upgraded existing	Upgraded: Philadelphia-Harrisburg New: Harrisburg Pittsburgh	All new	All new
Stations	Rehabilitated existing	Rehabilitated existing and new (high-level platforms)		Rehabilitated existing and new (high-level platforms)	All new
Maintenance Facilities	Upgraded existing	All new		All new	All new

maintained to very close tolerances. There are some performance advantages to this approach, but it is more costly to build and tends to be noisier than ballasted concrete-tie track.

The French have retained the more conventional tie and ballast approach but have developed a simple and effective track structure using duo-block concrete ties and spring-clip fasteners to maintain excellent alignment (line, surface and cross-level). The French track incorporates lighter weight rail (60 kg a meter, roughly 120 lbs/yd vs. 132 to 145 lbs/yd in the United States) and lighter ties, spaced farther apart (24" vs. 21") than in U.S. track. However, the trains are much lighter, and even at high speed, the wheel/rail forces are lower than on the Northeast Corridor. The French are reported to be maintaining their high-speed track to an extraordinary ±0.8 inch in cross level, and ±0.08 inch in line — a tolerance that is more than four times as stringent as required in the United States under FRA Class 6 (110 mph) track standards.[1]

U.S. track standards are currently based on use of wood ties and steel spikes, instead of concrete crossties and steel clips. Also, currently allowable speed in curves in this country is based on antiquated criteria. A waiver from, or revision to, the existing FRA rules would be required for HSR systems to exceed these limitations. Safety criteria would have to be developed and approved at the state and federal level.

Additional details of the track/guideway and structures envisioned under each alternative are provided below.

7.1.1 Alternative B

Existing track would be upgraded in selected areas where track condition currently limits speeds. (These improvements would have to be coordinated, of course, with signal system changes that might also be required before raising the maximum track speed.) This alternative would permit a maximum speed of 110 mph between Philadelphia and Harrisburg and 90 mph between Harrisburg and Pittsburgh. Speed still would be limited in curves, generally by the existing superelevation, because freight trains would continue to use the track. Existing track clearances might have to be increased at some locations to permit use of tilt-body equipment. Limited bridge changes might also be required to provide improved clearance.

7.1.2 Alternative C

Existing wood-tie track would be upgraded by replacing any existing bolted rail with continuous welded rail, renewing ballast and ties and rehabilitating interlockings. New track would be built to conventional U.S. track standards for 110 mph passenger train operation. Track would be maintained to FRA Class 6 standards. Track clearances would have to be improved to permit safe passage of either tilt-body or conventional designs. Where practical, a minimum of 14-foot centers between high-speed tracks would be provided. Even greater track-center clearances would be desirable between high-speed and adjacent, normal-speed track. Site conditions and operational considerations would dictate the final clearance criteria.

Some existing undergrade bridges would have to be widened or replaced to accommodate additional or realigned trackage. Similarly, selected overhead bridges would have to be lengthened or replaced (either in part or in whole) to provide adequate clearance. The costs for these categories of structures are included in the cost estimate.

A new 20-foot diameter bored rock tunnel near Spruce Creek would be needed to provide adequate line capacity at that location. This would most likely employ state-of-the-art rock boring techniques. Typical cross sections of at-grade track and tunnel are provided in the following section. The only cross-sectional difference between Alternatives C and D for new track is that the former would use wood ties and the latter concrete ties. Track for Alternative D would, of course, employ closer tolerances.

7.1.3 Alternative D

For the newly-constructed segments of Alternatives C and D, typical ballasted track sections have been developed. These sections allow for a minimum of 14-foot track centers for two or more tracks (refer to Figure 7-1). For elevated sections, a ballasted concrete deck is assumed and this is shown in Figure 7-2. Figures 7-3 and 7-4 show projected clearance requirements and general cross sections for single- and double-track tunnels.

The conceptual differences between track under Alternatives C and D are the use of concrete ties, tighter construction and maintenance tolerances, and longer (higher speed) turnouts under Alternative D.

At this initial stage, American Railway Engineering Association (AREA) standards were used to determine component costs. Examples of the AREA standards adopted for this study are:

- Length of Spiral (L) = $1.63\ E_u\ V$

  where:

  E_u = Unbalanced superelevation in inches
  V = Maximum speed in miles/hour
  L = Minimum spiral length in feet

- Allowable speeds for varying superelevations were computed from the equation $V_{max} = \sqrt{(E_a + E_u)/.0007\ D_c}$

  where:

  V_{max} = Maximum allowable operating speed in miles per hour
  E_a = Actual elevation of the outside rail over the inside rail in inches
  E_u = Unbalanced elevation in inches -- currently set by FRA rules at a maximum of 3 inches for conventional train equipment. (An E_u of 4.5 inches was used in this study for non-tilt-body equipment, and 9 inches of unbalanced elevation was assumed for tilt-body equipment.)

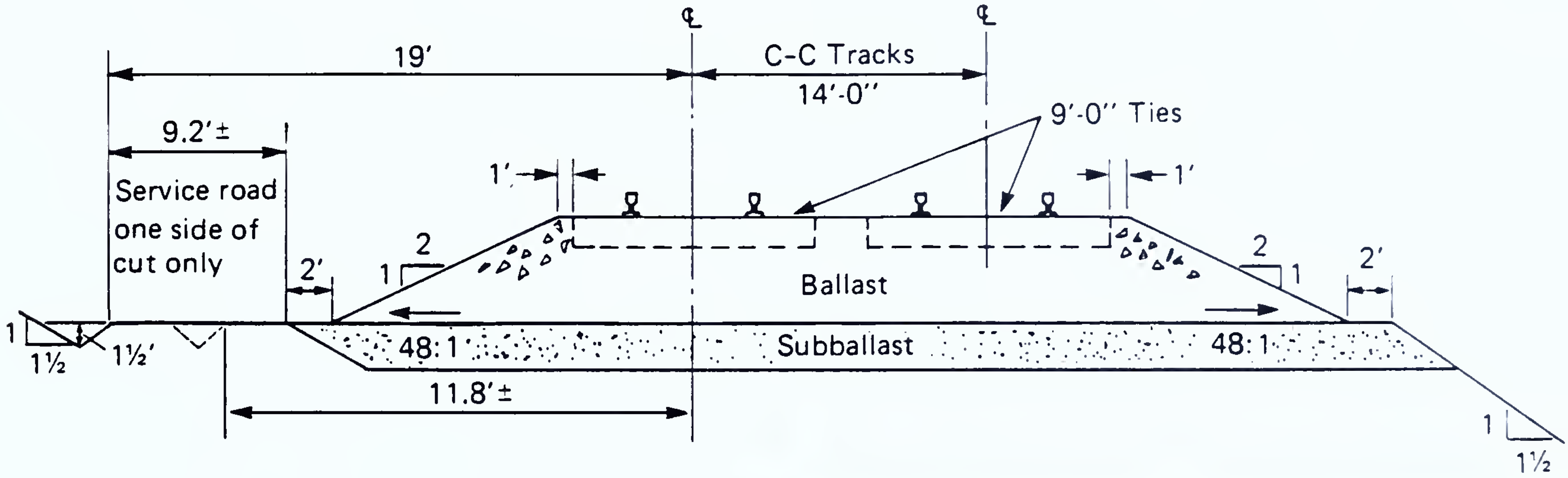


Figure 7-1
Ballasted Multiple-Track Section Alternatives C and D

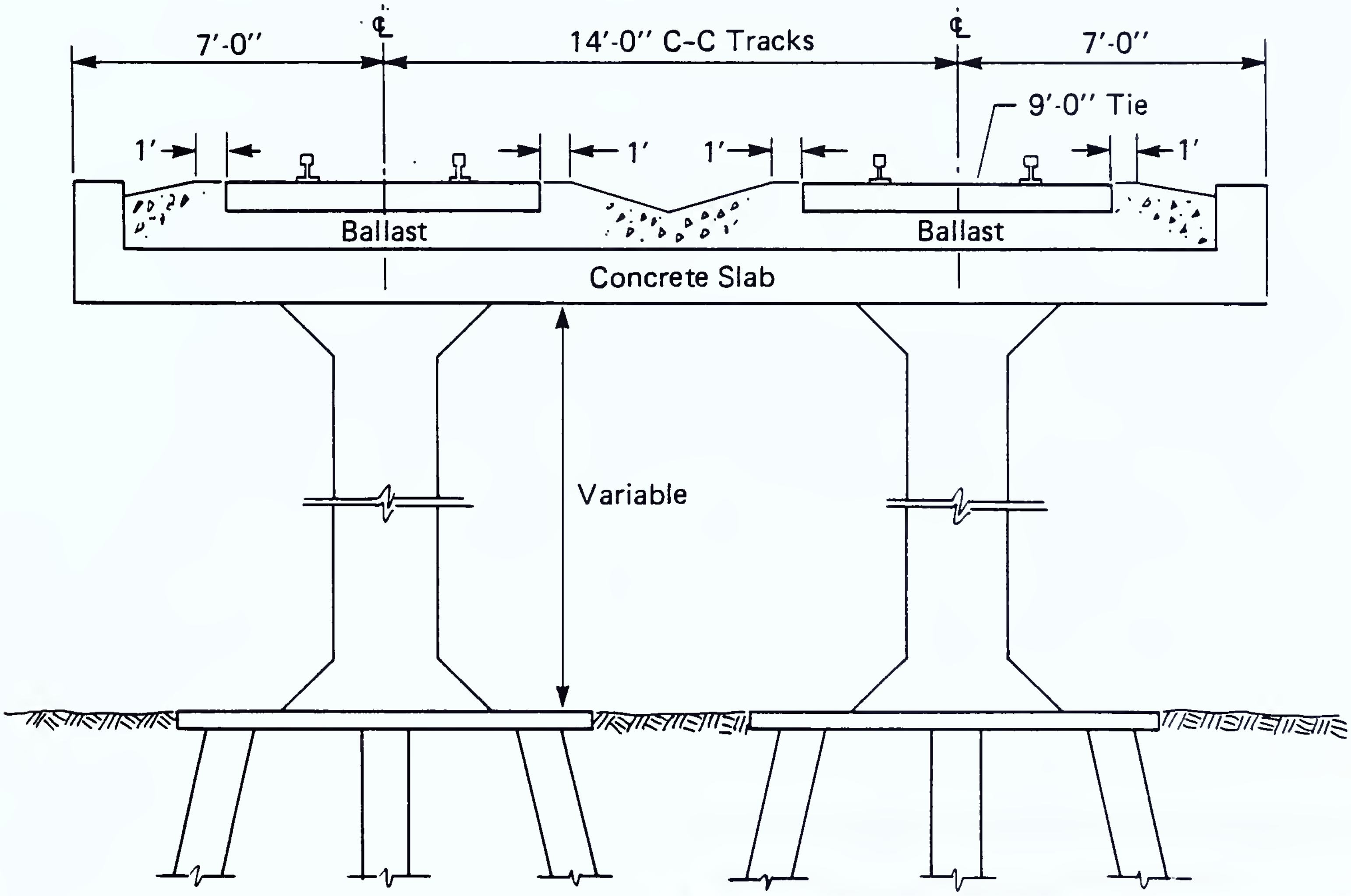


Figure 7-2
Aerial Structure Section Alternative D

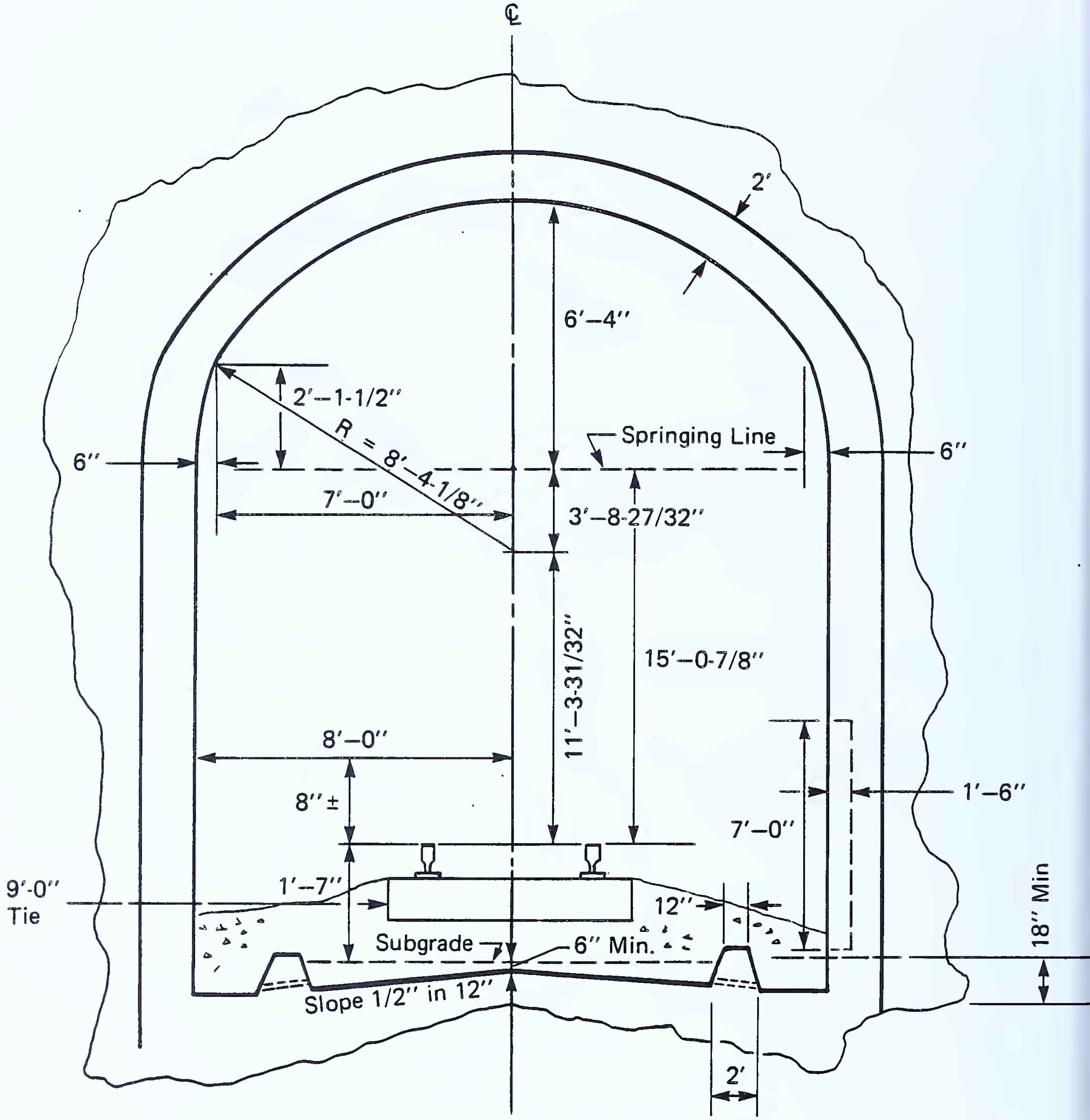


Figure 7-3
Ballasted Single-Track Tunnel Section Alternative C

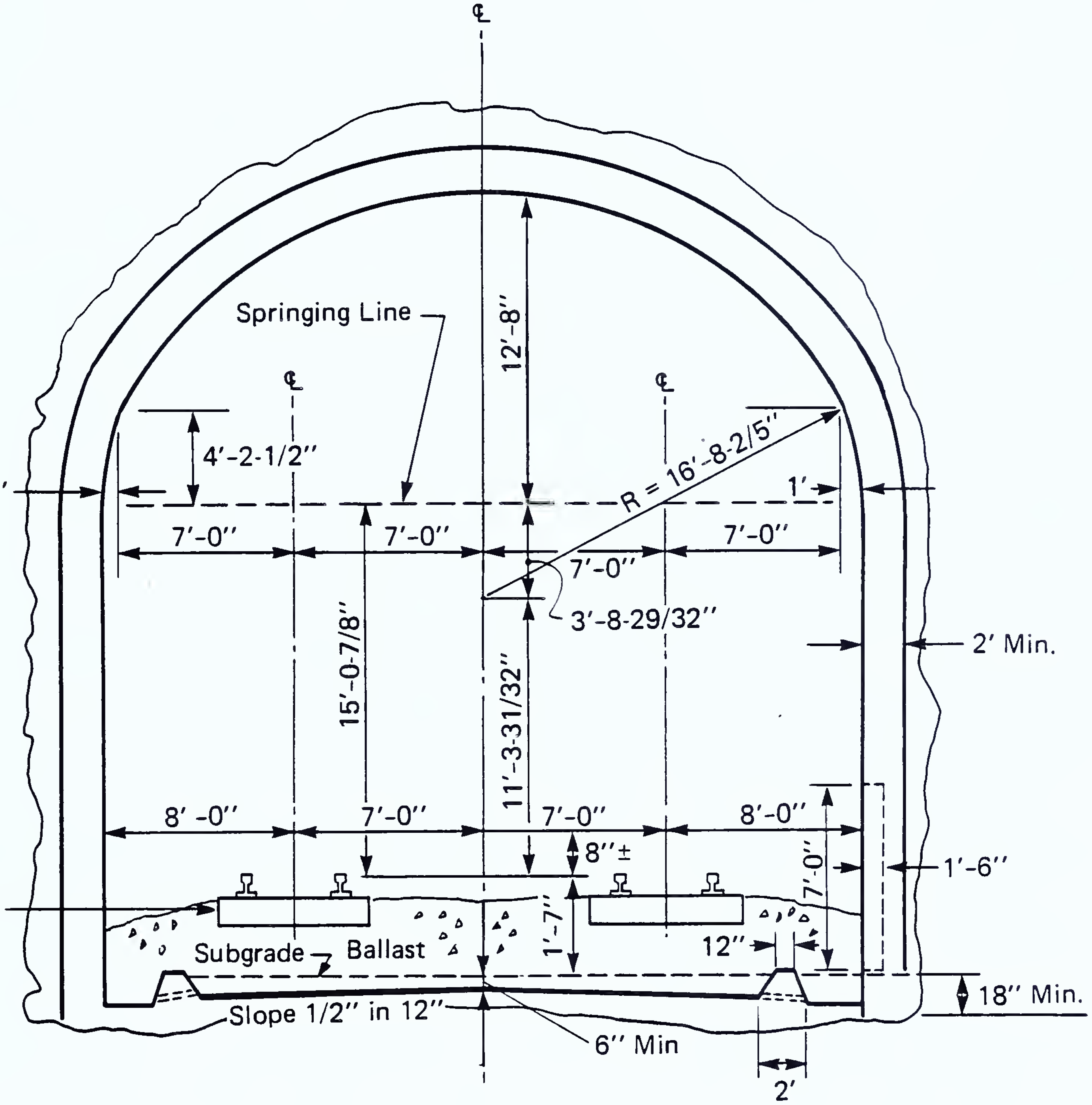


Figure 7-4
Ballasted Double-Track Tunnel Section Alternative D

D_c = Degree of curvature in degrees

- Vertical curve length (L) = D/R

  where:

  L = Length of vertical curve in 100-foot stations
  D = Algebraic difference of percent grades
  R = Rate of change of grade in percent (.05 for crest and sag)

- Clearances were assumed to be according to AREA standards
- New track construction assumed concrete ties on 22 inch centers, 12 inches of ballast under the tie and 12 inches of subballast
- Minimum tangent length between curves was assumed to be 100 feet
- Right-of-way requirements were based on limits of earthwork plus 10 feet
- Maximum depth of cut was assumed to be 300 feet. Cut typical sections allowed for an access road along one side of track. Maximum fills of 50 feet were assumed
- Structures were assumed to be ballasted deck structures
- A maximum 3.5 percent grade was used in developing the HSR alignment.

7.1.4 Alternative E

Because the Maglev system is still in the research and development stage, definitive information on guideway design is unavailable. For estimating purposes, conservative sections were drawn based on projected loads and geometrical requirements. For the EDS design, the top flange would be configured to fit the undercarriage assembly of the Transrapid 06, the design approach used for cost estimating purposes.

The guideway structure would consist of a precast, prestressed concrete box girder. The exact cross-sectional properties and amount of prestressing will depend on the design span. Three types of structures with generally increasing span lengths were considered for this study -- at-grade, elevated, and special. The type of structure chosen for any section depends on that section's topography.

An at-grade guideway is proposed for much of the route, particularly those segments located within the existing railroad right-of-way, for sections through tunnels, and for sections over relatively flat terrain where small cuts and fills will properly set the grade. This type of guideway would be lighter than other types since it was assumed that the structure could be almost continuously supported by spread footings. Refer to Figure 7-5.

Elevated guideway would be supported on reinforced concrete piers up to 50 feet high with span lengths of approximately 100 feet. Like the at-grade structure, the beam would be designed with uniform span lengths thus allowing the use of the fewest cross-sections possible. Figure 7-6 shows the double-track, elevated guideway on one pier cap, a scheme similar to the single-track design (Figure 7-7). Another scheme that may be necessary, especially in built-up areas, would provide separate piers under each guideway, giving the appearance of two independent single guideways.

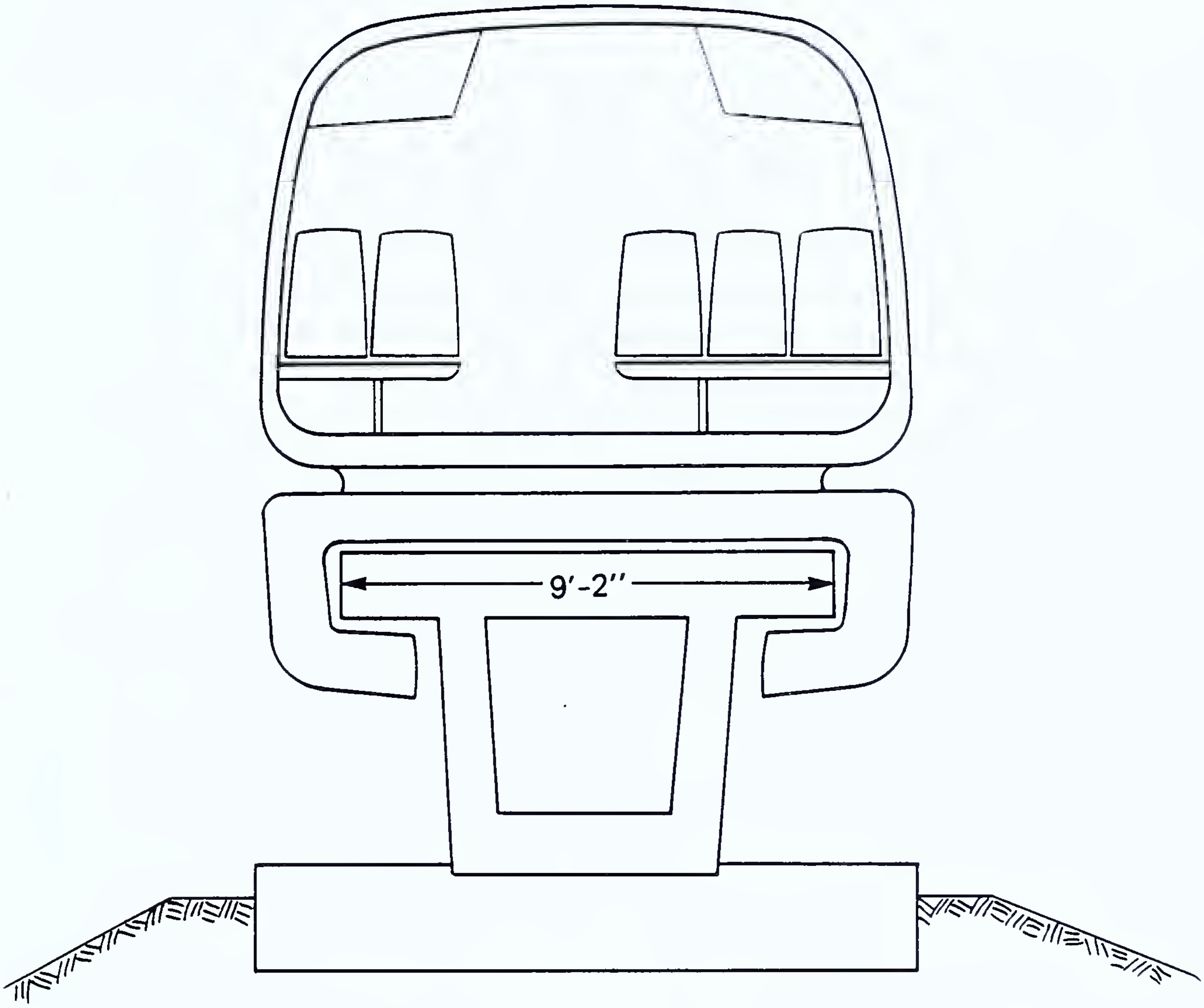


Figure 7-5

At-Grade Maglev Guideway Section Alternative E

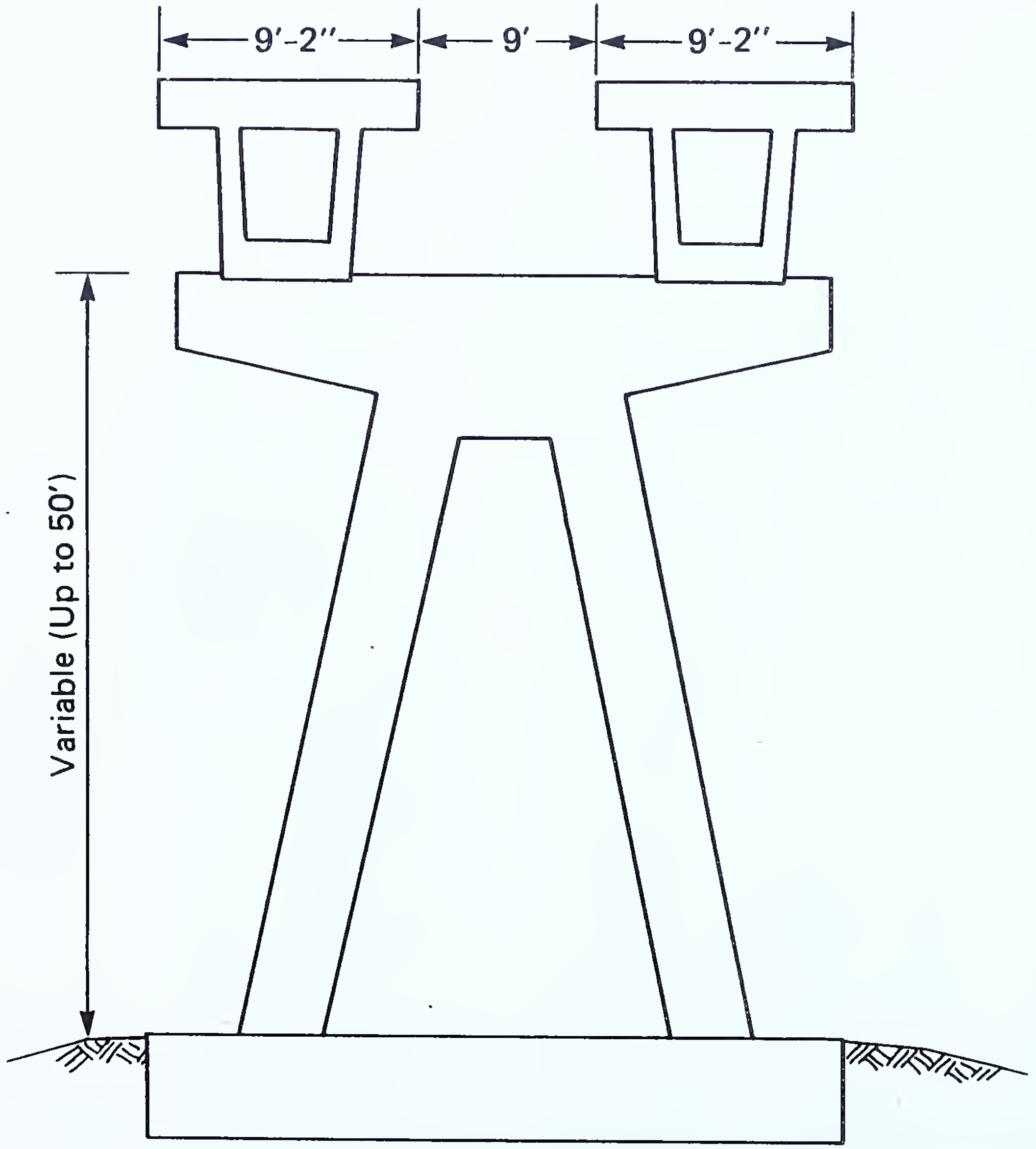


Figure 7-6
Elevated Double Guideway Section

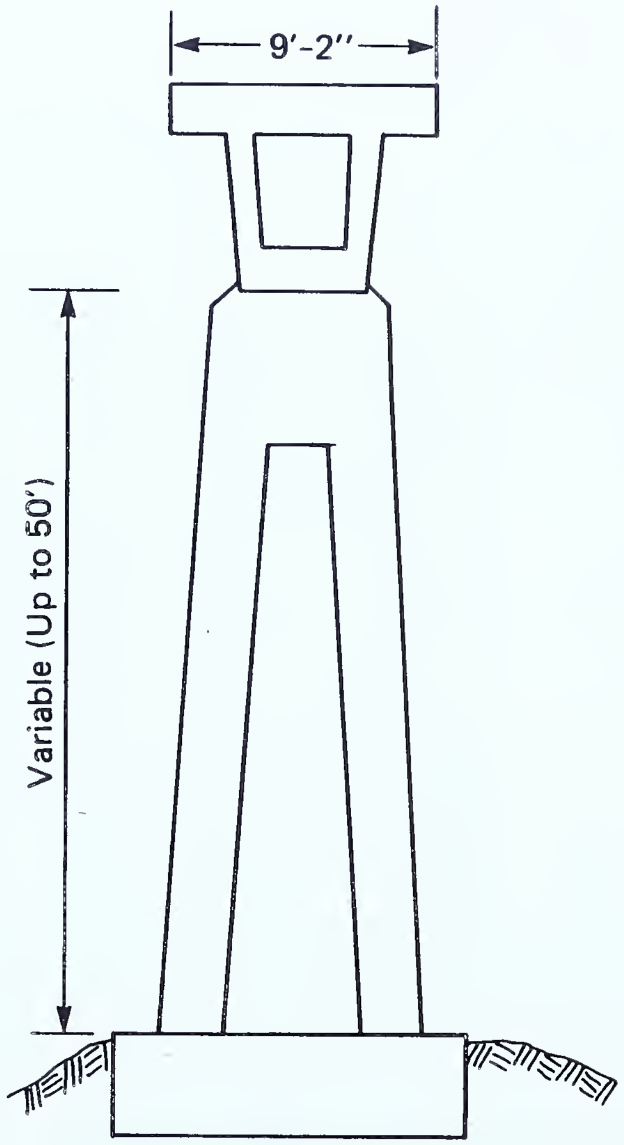


Figure 7-7
Elevated Single Guideway Section

The special structures category includes all sections of guideway in which the guideway beam must be supported by a uniquely designed structure. In general, special structures are required to handle long spans (more than 100 feet) and spans more than 50 feet above the ground. Typically, special structures would span rivers and major highways. Because each special structure would be designed individually, detailed costs could not be estimated. A factor of difficulty was used in estimating the cost of special structures.

Footings for elevated guideway and special structures would depend entirely on local soil conditions. Use of spread footings, piles and caissons is expected in place. Cost of footings for the elevated structure was based on large spread footings.

It should be noted that the design as presented is for comparative and discussion purposes only. Although it compares favorably with designs from other studies (notably studies in Canada and West Germany), the final design may very well be of different material or shape. Regardless of the design details, a project of this size would allow for mass production, providing the advantage of economies of scale and optimization of design.

Two Maglev switches are being tested at the Emsland facility for the TR-06. Each uses a slender steel guideway beam, several hundred feet long, that is bent elastically over the entire length of the switch. While both allow a top speed of 250 mph in the straight through direction, one allows a speed of 125 mph and the other of 55 mph in the branching direction. Changing the switch to the other direction takes about 20 seconds. Figure 7-8 illustrates the principle of the flexible steel switch.

7.2 GRADE CROSSING ELIMINATION AND RIGHT-OF-WAY FENCING

A high percentage of railroad-related accidents in the United States occurs at grade crossings. Accidents result from equipment failure, motorist disregard of the warning system, or lack of an adequate warning system. A major problem arises from motorists thinking they can beat a train through a crossing when in fact a collision is imminent.

High-speed trains can approach crossings so much faster than conventional trains that normal protection devices (gates and/or flashers) are usually inadequate. Grade crossings in sections where high-speed trains share the right-of-way with freight traffic are particularly difficult to signal and control because of the speed differential.

Fencing is required to help keep animals and/or trespassers off the right-of-way. Experience has shown that fencing is not totally effective, particularly in urban areas; however, it does reduce casual intrusions. Electrification poses an additional danger to trespassers who may come in contact with a live wire. Additional fencing, particularly on overhead bridges, is required to minimize this potential hazard.

Grade crossing elimination and fencing are both desirable safety features; however, inevitably, their cost must be balanced with their benefit. Varying levels of each are proposed under Alternatives B through E.

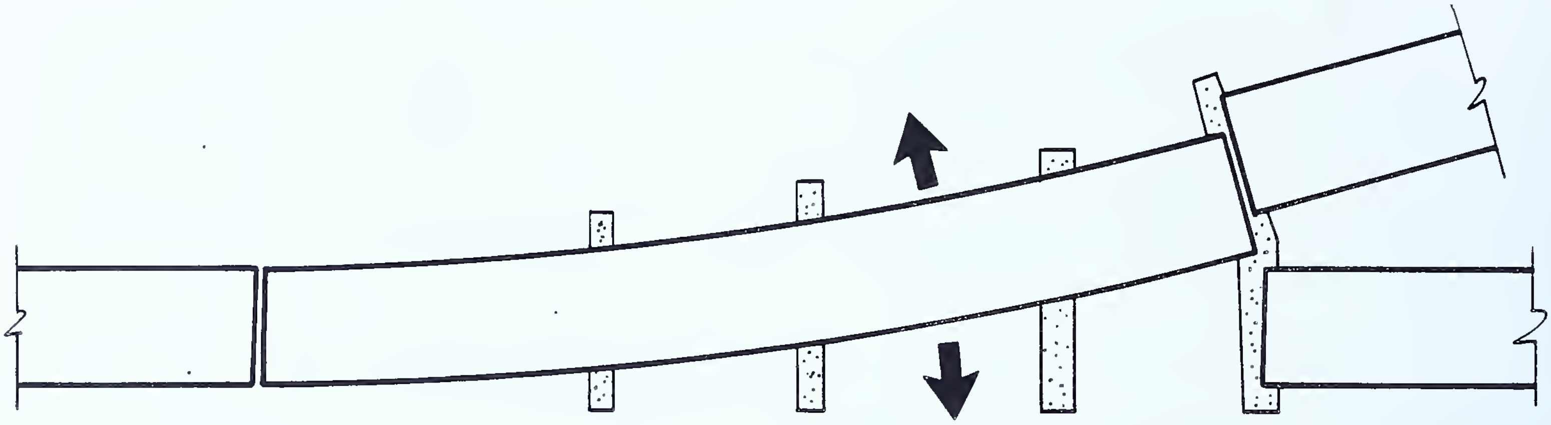


Figure 7-8
Flexible Steel Switch
Alternative E

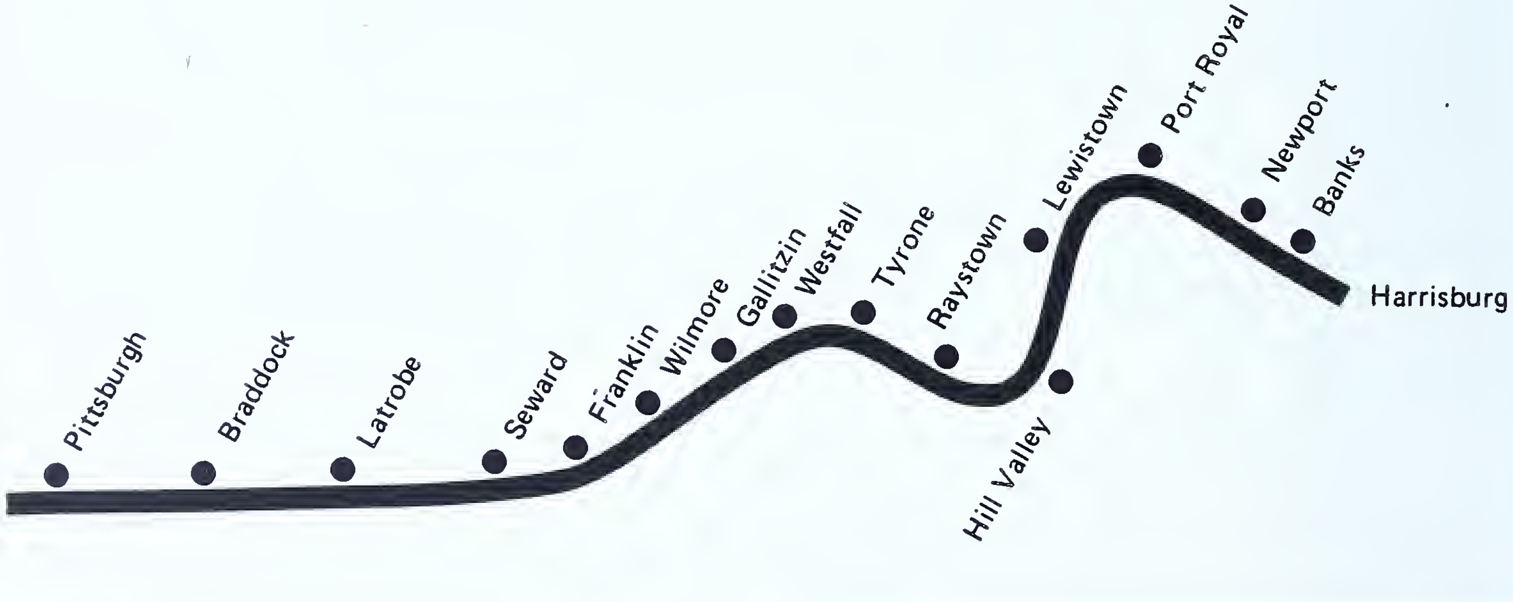


Figure 7-9
Proposed New Substation Locations
Alternative C—Electric

7.2.1 Grade Crossing Elimination

Grade crossings can be eliminated by means of grade separation, rerouting either the track or the road, or closing the crossing and rerouting highway traffic. Grade separation, accomplished by means of an overpass or underpass, is the most expensive means, but is often the only acceptable solution. Private crossings can sometimes be eliminated by agreement, usually involving compensation for loss of cross-track access.

Elimination of all grade crossings is probably not practical under Alternative B, and possibly a few would remain under Alternative C. In Alternative B, for lightly used crossings, particularly in rural areas, remaining grade crossings would be protected by an upgraded warning system (gates and flashers). The cost of eliminating all existing grade crossings was included in the Alternative C cost estimate.

Under Alternative D, all grade crossings must be eliminated because the combination of high speeds and frequent service makes it very difficult otherwise to maintain safety. Complete elimination of crossings was provided for in the Alternative D cost estimate.

Due to the configuration of the guideway, it is physically impossible to permit crossings at grade in Alternative E. Since only a small proportion of the guideway is on the existing alignment, however, only a few grade crossings would need to be eliminated. Over the majority of the route, all new construction would incorporate elevated guideway over potential conflicts. These costs were included in the estimate.

7.2.2 Fencing

Right-of-way fencing is proposed to different extents under all of the alternatives. In addition, overhead bridge fencing is proposed for Alternatives C-Electric, D, and E.

Under Alternative B, existing right-of-way fencing would be retained, and only very limited new fencing would be provided in areas of frequent intrusion. Under Alternative C, 10 percent of the length of the entire right-of-way is proposed to be fenced on both sides. This would be primarily in urban areas, parklands and near farmland, where livestock occasionally wanders onto the tracks. Under C-Electric, overhead bridge fencing also would be needed.

Under Alternatives D and E, all at-grade or in-cut sections (i.e., all non-elevated or tunneled sections) and all overhead bridges are proposed to be fenced. Where the high-speed track or guideway lies adjacent to other track, inter-track fencing may be required. (In some cases, this may be in lieu of the right-of-way fencing.) At interlockings that involve high-speed and freight or other passenger trackage, gaps would have to be left in the inter-track fencing; otherwise, tracks would generally be separated by fencing to protect railroad workers on adjacent tracks as well as the public.

7.3 ELECTRIFICATION

The primary advantage of electrification is that higher power levels could be provided, allowing higher speeds and acceleration rates than are possible with diesel-powered equipment. Another advantage is that a local energy source, Pennsylvania coal, could be used to power the trains. Electrified operation has environmental and operating cost advantages over diesel operation, but at increased initial capital costs.

Alternatives B and C (base case) would not use the existing electric traction system between Philadelphia and Harrisburg and would not require the electrification system to be extended to the west. It was assumed, however, in preparing the cost estimate, that the existing electrification system would not be abandoned or dismantled; and, in fact, where proposed track shifts were expected to interfere with existing catenary poles, the cost to relocate the catenary structure was included in the estimate.

The following subsections describe electrification facilities required under Alternatives C-Electric, D, and E.

7.3.1 Alternative C-Electric

The Amtrak route between Philadelphia and Harrisburg is electrified using 11.5-kV, 25-Hz traction power. The design of the overhead distribution system is a compound catenary of the variable tension type. Signaling and communications facilities are suitable for operation with 25-Hz traction power. Portal construction and cross-catenary construction are used for catenary support structures.

East of Harrisburg, freight service uses only diesel motive power, and passenger service is provided using both diesel locomotive-hauled trains and electrified MU cars. These MU cars are capable of operation at up to 110 mph; however, the current maximum speed is 90 mph.

The Conrail line between Harrisburg and Pittsburgh is not electrified. Diesel locomotives pull both Conrail freight service and Amtrak's limited passenger service. Existing signals and communications facilities west of Harrisburg are incompatible with electrified operation.

The discussions which follow have been divided into "East of Harrisburg" and "West of Harrisburg" because the modifications necessary for high-speed passenger service are different.

East of Harrisburg

In the urban areas east of Harrisburg, the high-speed passenger service for Alternative C-Electric will operate in the existing Amtrak right-of-way, sharing some tracks with local passenger service and freight service. Most of the existing track, traction power catenaries, signals and communications in these urban areas will be retained and upgraded.

In rural areas, two tracks will be dedicated to high-speed passenger service. These tracks may be realigned in curves or shifted to provide additional clearance or be newly constructed to reduce the need for speed restrictions. Adjustments to existing catenary would become necessary where these track changes are made. Where there is portal construction or cross-catenary construction with relocated or new track within the existing structure, the catenary would be modified or relocated to maintain its position above the new track. The reconstructed catenary would use the same basic variable-tension design now in use.

Where curve realignments are planned and the realigned track would fall outside the existing structures, or conflict with existing structures, new structures would be required. These new structures would use poles with cantilever arms supporting a variable-tension compound catenary of the same basic design as now used. This approach avoids costs associated with transition sections between two catenary designs at each end of the relocated catenary.

The existing frequency changer substations, 132-kV subtransmission lines and transformer substations are believed to have ample capacity for the high-speed passenger service.

West of Harrisburg

In downtown station areas, the high-speed passenger service will operate in the existing Conrail right-of-way sharing tracks with Conrail freight service. In rural areas, one to two tracks would be dedicated to the high-speed passenger service. Installing these dedicated tracks in the existing Conrail line would involve major realignment, major track renewal and/or new track to reduce the need for speed restrictions. Tracks used for passenger operations would be electrified. The new electrification facilities and other necessary changes are discussed in the following paragraphs.

Voltage/Frequency Recommendations West of Harrisburg

In developing an electrification system to serve as a cost basis for Alternative C-Electric, electrification frequencies of 16 2/3 Hz, 25 Hz and 60 Hz were considered. In Europe, 16 2/3 Hz is used extensively. This is one-third the frequency used for utility distribution there, and is easily produced in motor-alternators. There is no similar advantage for 16 2/3 Hz in the United States, and this frequency was not considered further.

There is no simple technical reason for choosing between 25-Hz and 60-Hz electrification. Modern locomotives and MU cars using rectifier-type propulsion subsystems provide essentially equal performance on either frequency.

Three electrification systems were examined for this corridor:

- A 60-Hz, 2-wire (catenary and rail), center-fed system supplied by individual substations with phase breaks midway between substations.
- A 25-Hz, 2-wire (catenary and rail) system supplied by individual solid state frequency converter substations operating in parallel (synchronized).
- A 25-Hz, 2-wire (catenary and rail) system supplied by three central (rotary) frequency converter stations interconnected by single-phase, high-voltage 25-

Hz transmission lines. These transmission lines would be constructed as an overbuild on the catenary structures. Power to the catenary would be supplied by step-down transformers in substations at less than 20-mile intervals along the right-of-way. This system would be quite similar to the existing electrification of the Northeast Corridor.

A comparison of the construction costs for the three systems described above showed a significant cost advantage for the 60-Hz electrification. Although not quantified, the difference in maintenance costs between these systems would also favor the simpler 60-Hz system.

Similarily, the choice between 12.5-kV, 25-kV, and 50-kV operation with 60-Hz traction power was examined. The use of 12.5 kV results in heavier catenary currents, and higher voltage drop per mile, requiring closer spacing of substations. Utility transmission lines are not available in many cases for these closer spacings. The use of 50 kV requires larger clearances to the sides and above the catenary. On the Harrisburg-Pittsburgh corridor, there are many structures that do not provide adequate clearance for 50 kV but are adequate for 25 kV. Other structures that need improved clearance for 25 kV need greater improvements for 50 kV. These factors led to the choice of 25 kV electrification.

Therefore, 25-kV, 60-Hz traction power electrification is recommended for Alternative C-Electric west of Harrisburg.

Voltage/Frequency Change Point

Acceptance of the recommendations above will make it necessary to have only one voltage/frequency change point per track. This would be at Harrisburg where transitions would be made between 11.5 kV/25 Hz and 25 kV/60 Hz. Such voltage/frequency change points are used regularly in Europe. Locomotives and MU cars which operate through voltage/frequency change points must have sensors, interrupters and tap changers. Wayside equipment to operate the sensors must also be provided.

Substation Spacing and Rating West of Harrisburg

The existing right-of-way has limited sources of supply of power for propulsion. It is normally presumed that 25 kV/60 Hz, 2-wire electrification can operate satisfactorily with substations 20 to 25 miles apart. There are utility transmission lines available at about these spacings near the locations shown in Figure 7-9. Some of these utility transmission lines operate at 230 kV, others at 115 kV.

Each substation is assumed to be fed by a single incoming utility line and to be equipped with two equal-sized, two-winding power transformers. A standardized design of 15 MVA transformers would be specified. This arrangement would permit normal service with two trains accelerating within each section, and full performance would be maintained in the event of one transformer being out of service. Each substation would be "backed up" by an adjacent substation in the event of loss of its power source. Catenary sections powered from a disabled substation would be connected to and fed from adjacent substations. Some train performance reductions might be necessary under this circumstance. Complete power loss at a substation is rare, and fully redundant backup would seldom be required for more than a few minutes. The utility lines likely to be chosen as power sources are sufficiently diversified that simultaneous loss of adjacent substations would occur only under catastrophic conditions.

The utilities supplying power will require the customer to pay the costs of connecting the railroad substation to their transmission lines. This has been considered in the preparation of the cost estimate. It has been assumed that no new generation capability would be required.

Catenary Type West of Harrisburg

The electrical energy requirements for the train can be provided using a standard tangent-chord catenary configuration located above the track, avoiding the need for paralleling, supplemental conductors or feeders along the right-of-way. Three basic catenary configurations could provide the required ampacity. These are:

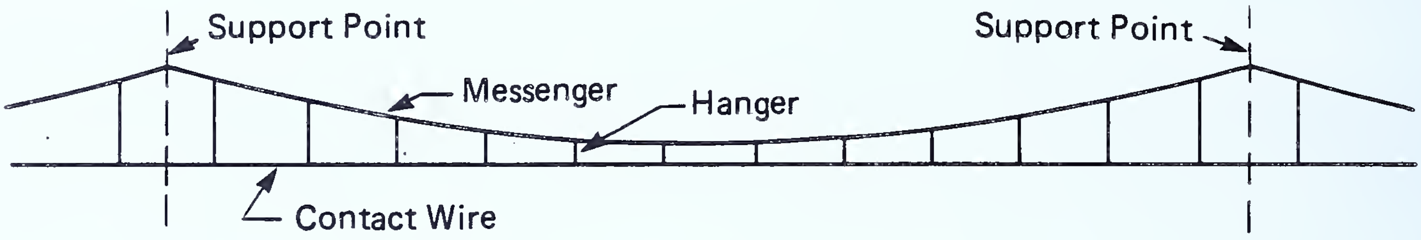
- Simple catenary comprised of one contact wire and one supporting messenger wire.
- Simple stitched catenary, comprised of one contact wire and one supporting messenger wire with a short length of auxiliary messenger at each supporting structure.
- Compound catenary comprised of one contact wire, one supporting messenger and a continuous auxiliary messenger.

The configuration of these catenary styles is shown in Figure 7-10.

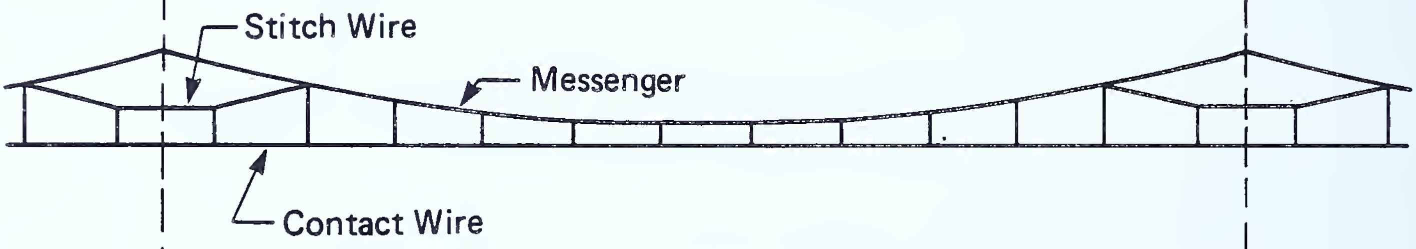
The proposed maximum operating speed of 110 mph under Alternative C dictates the use of either simple stitched catenary or compound catenary for acceptable current collection with single- or multiple-pantograph collectors. As the projected life cycle cost for both styles of catenary are essentially the same, the most reliable catenary system should be used. A compound catenary system, similar to the existing catenary used on the mainline between Philadelphia and Harrisburg, is proposed. This style of catenary is simpler to install, requires minimum maintenance and is more tolerant to damage from pantographs and broken conductors than the alternatives.

The tension of the conductors can be maintained at a constant value, or permitted to fluctuate in response to variations in ambient temperature or conductor icing. In a constant-tension system, the catenary is terminated on a mechanical device which compensates for the expansion and contraction of the conductors. The constant conductor tension avoids variations in the profile of the contact wire thus maintaining electrical clearance to rail equipment, grade crossings and bridge decks throughout the temperature range — so long as the weight of the catenary is not significantly increased. However, in the event that ice forms on the conductors, the messenger sag under this design can become excessive.

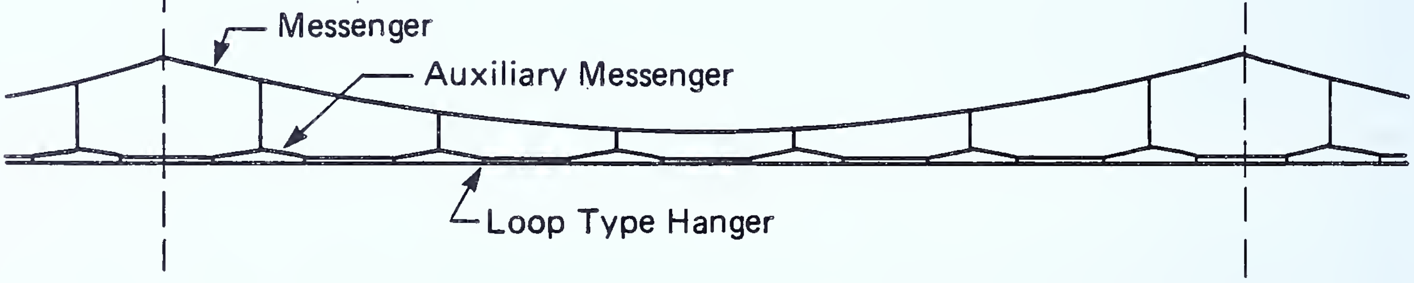
With a variable-tension system, the conductors are terminated directly onto supporting structures. Changes in conductor temperature result in acceptably small variations in the profile of the contact wire and the electrical clearance to rail equipment, grade crossings and bridge decks. At 60°F, the usually accepted mean ambient design temperature in the study area, the contact wire profile would be



Simple Catenary



Simple Stitched Catenary



Compound Catenary

Figure 7-10
Candidate Catenary Types

essentially a straight line between adjacent supporting structures. When temperatures fall below 60°F and before ice has formed on the conductors, the contact profile would "hog" upwards. When the temperature rises above 60°F, or when ice has formed on the conductors, the contact wire will "sag" downwards.

Because a major portion of the route passes through the Allegheny Mountains where ice regularly forms on conductors, a fixed-termination, variable-tension catenary would be the most suitable and economical method of conductor tensioning. Moreover, with this method of tensioning, the need for ice-melting apparatus would be avoided, and the designed electrical clearances above top of rail can be maintained.

Therefore, the use of a tangent-chord, fixed-termination, variable-tension, compound catenary for the extension of the existing electrification to Pittsburgh is recommended.

Catenary Structure Type, Size and Design West of Harrisburg

The types of catenary supporting structures that can be used within the existing right-of-way west of Harrisburg are limited by Conrail's maintenance practices, which require an 18-foot clearance between the centerline of the nearest track and the face of new supporting structures. This large side clearance permits off-track vehicles to perform maintenance without interrupting train operations. Structure-setting distances of this order preclude the use of European-style, "live," single-track cantilever assemblies, comprised of insulators and galvanized steel tubes and hardware, as well as the "grounded" steel bracket assemblies fabricated from rolled steel sections. Because of these restrictions, the only structure options considered were cross-catenary structures and portal structures. Previous studies have established that a cross-catenary design is the more economical of the two.[2]

The high operating speed of the proposed passenger service dictates that the track and catenary must be maintained to close tolerances. High operating speed combined with a project life in excess of 30 years requires a durable version of the cross-catenary structure. Consequently, the following types of supporting structures are recommended for electrification west of Harrisburg: (The structures are listed in their most cost-effective order.)

- Cross-catenary with transverse guyed steel poles as shown in Figure 7-11.
- Cross-catenary with free-standing steel poles, which will cost about 10 percent more.
- Portal structure, consisting of free-standing steel poles with a transverse steel beam, which will cost about 20-25 percent more.

The type of structure shown in Figure 7-11 is equally well suited to supporting catenary systems over single or multiple tracks where the right-of-way is wide enough to accommodate the transverse guys. Otherwise, free-standing poles must be used. Use of wood poles is not recommended because of their shorter service life.

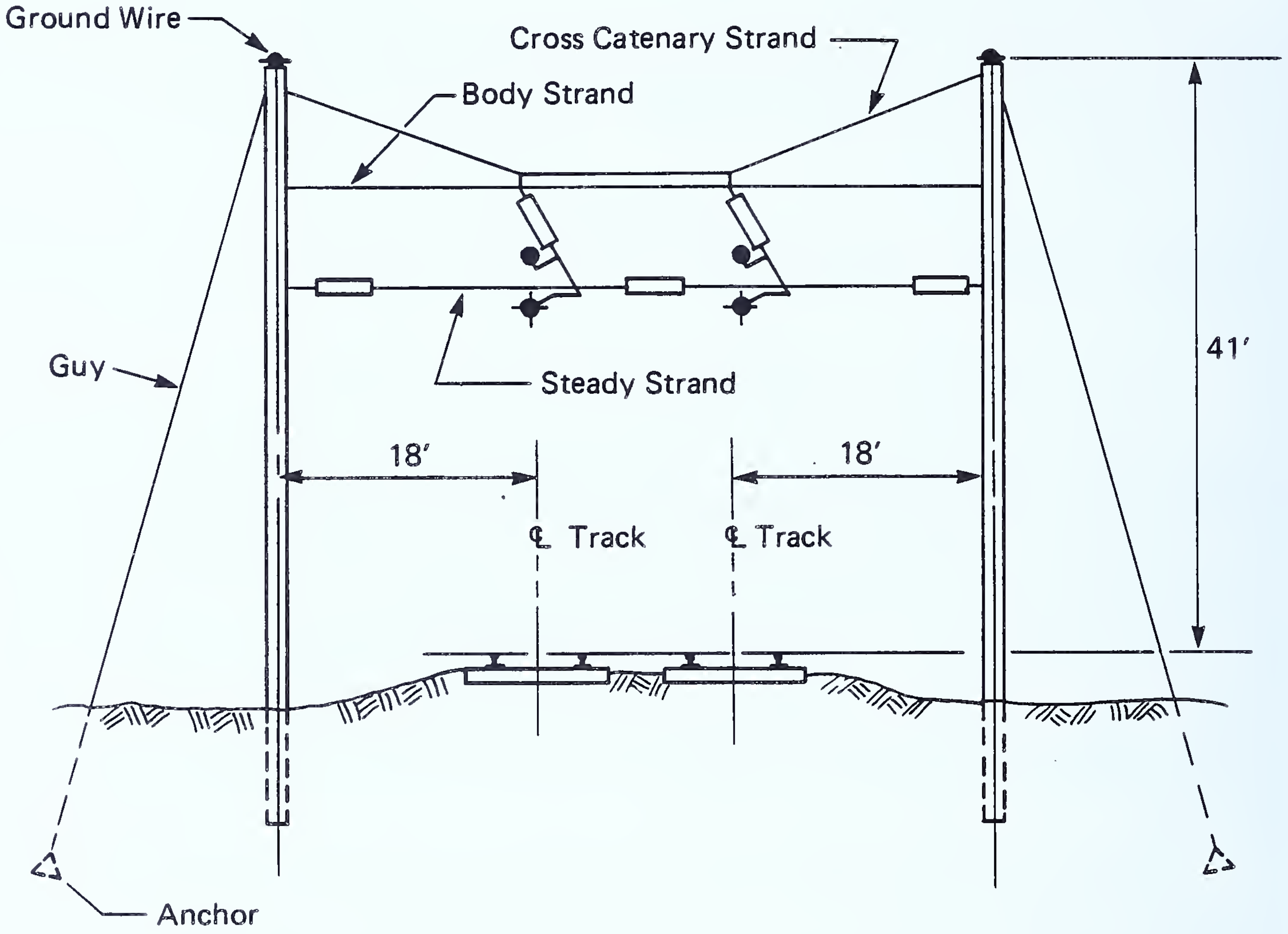


Figure 7-11
Steel Pole Catenary Structure with Gu
Alternative C—Electric

Catenary Alignment and Maximum Span Length

Catenary alignment and maximum span length must be designed to keep the contact wire within the usable portion of the pantograph collector head on both tangent and curved track, considering wind velocity, vehicle dynamics, possible track shifts and normal tolerances.

The alignment is controlled by catenary supporting structures spaced at intervals along the right-of-way. Because the initial construction and subsequent maintenance cost of these structures represents the major portion of the life-cycle catenary system costs, the number of supporting structures has to be kept to a minimum. The actual spacing of supporting structures varies according to track alignment, location of turnouts and crossovers, and location of overhead bridges, undergrade bridges and grade crossings. Recommended spacing of supporting structures normally varies from a maximum of 240 feet on tangent track to a minimum of 135 feet on curved track, depending on degree of curvature. A suitable catenary alignment can be achieved with the recommended structure spacing by offsetting the contact wire away from the track centerline, normal to the plane of the rails, at each supporting structure. This offset, or stagger, as it is more commonly called, maintains the proper relationship between the contact wire of the tangent-chord catenary and the pantograph collector on curved track. On tangent track, it serves to distribute wear more evenly over the length of carbon inserts on the collector head.

Conductor Size - Messenger, Auxiliary Messenger and Contact Wire

The size of the messenger (0.545-inch diameter), auxiliary messenger (0.388-inch diameter), and contact wire (212 kcmil) for the recommended three-wire fixed-termination, variable-tension catenary was based on a 900-ampere rating with the proposed 25-kV, 60-Hz traction power system. This is about twice the maximum current normally demanded by a locomotive such as the AEM-7. It was also necessary to consider the mechanical strength of the catenary when selecting the wire size. If a smaller wire size were selected, it would be necessary to reduce the lengths of the spans between structures to assure adequate strength with wind and/or ice loading. The proposed wire sizes would carry the necessary current while minimizing the combined costs of the structures and catenary.

7.3.2 Alternative D

Tests made on the Northeast Corridor several years ago using modified Metroliners demonstrated the difficulty of obtaining satisfactory catenary/pantograph dynamics at speeds above 120 mph with heavy catenary such as exists between Philadelphia and Harrisburg. For satisfactory catenary/pantograph dynamics up to 160 mph or more, the catenary must have a light, flexible construction with no "hard spots." The use of 25 kV permits a lighter catenary construction than the use of 11 kV and therefore is recommended at least in the high-speed segments of the route. The existing structures could be used to support the new, lighter-weight catenary between Paoli and Harrisburg.

A voltage/frequency change point would be required where the high-speed passenger service changes between 11-kV/25-Hz electrification and 25-kV/60-Hz electrification. This point should be located somewhere west of Paoli to avoid affecting existing SEPTA service.

West of Harrisburg, the high-speed route would be electrified using new structures, catenary and substations, which are described below.

Substations

New substations will be required to energize the catenary from the voltage/frequency change point to Pittsburgh. In general, substations would be located at 20- to 25-mile intervals. Each site would be located near a utility transmission line to minimize connection costs. East of Harrisburg there are many transmission lines from which a choice may be made. West of Harrisburg, the locations shown in Figure 7-9 are proposed for Alternative D. Each substation would be of a standard design, similar to the design for Alternative C.

Catenary

A tangent-chord form of construction is recommended for the longitudinal catenary, both for performance and for ease of construction. To ensure that the pantograph makes continuous contact in a satisfactory manner, the catenary system would be designed to follow the horizontal track alignment by being pulled into a series of straight lines, or chords, over the track by "pull-off" assemblies on the lineside structures.

Compound catenary construction, employing constant-tensioning apparatus, is recommended for the high-speed segments of the route. This type of construction consists of three wires in the same vertical plane — an upper messenger wire, an intermediate auxiliary messenger supported by hangers, and a lower contact wire — all hard-drawn, high-conductivity, copper conductors. For estimating purposes, 4/0 messenger, 2/0 auxiliary messenger, and 212 Kcmil contact wire were assumed. Copper jumpers will equalize current distribution between the catenary conductors. The jumpers form a direct electrical connection between the catenary messenger, the auxiliary messenger and the contact wire.

The constant-tension compound catenary will be designed to provide a normal, continuous, full-tension length of about 5250 feet. To minimize the use of splices which create hard spots and detract from overall performance, the ends of the conductors will be overlapped for one span before being terminated. Overlapping spans at the end of each tension length will comprise a standard arrangement of parallel longitudinal catenaries with gradual vertical transition in the outgoing wires at the ends of the span to permit smooth, arc-less transfer of the pantograph from one contact wire to another.

Tension in the catenary wires will be maintained substantially constant, within limits of the operating temperature range, by automatic tensioning devices at the ends of each length. While the catenary system possesses inherent flexibility, a certain amount of rigidity is needed to provide near-uniform pressure between pantograph and contact surface, particularly where maximum speeds are to be attained. This can be achieved by increasing the contact wire pre-sag to counteract excessive amplitude variations in the pantograph trajectory.

Stitch wires will be employed at the supporting locations which will tend to soften the transition from one span to another. Simple stitched catenary, shown in Figure 7-10, is used on the French Paris-Southeast Line.

The catenary supporting structures will be spaced within each tension length, generally according to track curvature up to a maximum of 240 feet. Certain locations, such as low overhead bridges, may require special structure spacings to permit catenary grading.

The planned route alignment passes through a section of Pennsylvania that regularly experiences winter weather during which radial ice formation can build up on wires and structures. The planned one-hour headway between trains for the high-speed passenger service would not heat the catenary enough to retard ice formation. Constant tension catenaries must be de-iced. For this, SJ in Sweden and other railroads in similar icing areas have used resistive load banks. A similar technique would probably be necessary in Pennsylvania.

Catenary Structures in Newly Electrified Areas

In order to operate the railroad exclusively for passenger trains, and provide continuity of very high speeds, the track must be designed, built and maintained to precise tolerances. One of the prerequisites would be to minimize variations in horizontal track alignment and endeavor to keep the track as straight as possible.

This would permit standardization and design uniformity in catenary supporting structures and components.

While the size and strength of supporting structures and assemblies are necessarily varied to suit different loading requirements, the small variation in imposed loads from the catenary system, derived from the benefits of virtually straight track, together with a refinement of side clearances, will keep to a minimum the number of sizes and strengths of structural members needed.

Under this alternative, a self-supporting (unguyed) wide flange section is proposed as the basic supporting structure in normal open-route areas. The maximum loading conditions, will permit a relatively slender mast design with adequate strength and safety factor to satisfy conditions over a major portion of the route. With constant-tension catenary, longitudinal forces which are transferred to the structures are minimal except at the ends of the tension sections. Thus, most structures do not require guy wires. For maximum protection, masts should be of a corrosion-resistant material, the principal advantages being that it needs no initial galvanizing treatment and should never require painting.

For trouble-free performance at high speeds, the catenary must be maintained within precise limits of its design position. Foundations for the supporting masts must therefore be designed to provide negligible movement at ground level.

7.3.3 Alternative E

As discussed earlier, Alternative E is based on the German TR-06 or Japanese MLU-001 prototype designs currently being tested at Emsland, West Germany, and Miyazaki, Japan. In both designs, the train is propelled, levitated and guided by electric magnetic fields. For discussion and cost estimating purposes, the TR-06 approach has been adopted in this study. This subsection describes the levitation, propulsion and guidance subsystems as well as electrification because they are an integral part of the Maglev concept.

Levitation System

When the TR-06 vehicle is stationary, it rests on skids that are aligned with skid rails on the top surface of the guideway. When the levitation coils are energized, attractive forces are created, raising the vehicle a few millimeters off the skids. Horizontal magnetic forces between the levitation coils and the long stator also provide thrust, helping to propel or brake the vehicle.

Propulsion System

A linear synchronous motor (LSM) is used to provide propulsion. The LSM stator is suspended from the guideway structure. Propulsion motor controls are housed in enclosures under the guideway, provided at intervals of about 0.25 mile. The LSM field magnets are mounted on the vehicle beneath the stator. When the stator is energized with a constant value of current, the LSM produces a constant thrust regardless of operating speed. (If the thrust is in the direction of motion, acceleration occurs at a value proportional to thrust minus drag. If the thrust opposes the motion of the train, braking occurs at a value proportional to thrust plus drag.)

Guidance System

Vehicle guidance would be provided by a reaction rail on either side of the guideway and by electromagnets mounted on each side of the vehicle. As the vehicle moves, the electromagnets produce a circulating current and a magnetic field in the reaction rails. The forces produced are inversely proportional to distance between the electromagnets and the reaction rails, tending to keep the vehicle centered between the reaction rails. The forces are proportional to speed so vehicle movement from the centerline is limited at all speeds.

Linear Generator

The TR-06 vehicle designers have developed a linear generator winding in the pole faces of the on-board propulsion field magnets. Movement of the vehicle on the track produces a modulation of the magnetic field in the pole faces producing a voltage in the linear generator winding. The output from the linear generator winding is rectified and charges an on-board battery. All on-board loads operate from the battery. There is a threshold speed below which the linear generator output is too low to charge the battery.

Power Supply

Power to operate of the magnetically levitated train for Alternative E would be purchased from the electric utilities through whose franchise territory the route passes. A one-line diagram of a typical substation and typical inverter station is shown in Figure 7-12. At intervals of about 20 to 25 miles substations will be energized from a 115-kV or 230-kV transmission line of the local utility. The exact distance between substations will depend on where each can most economically be supplied by the utility.

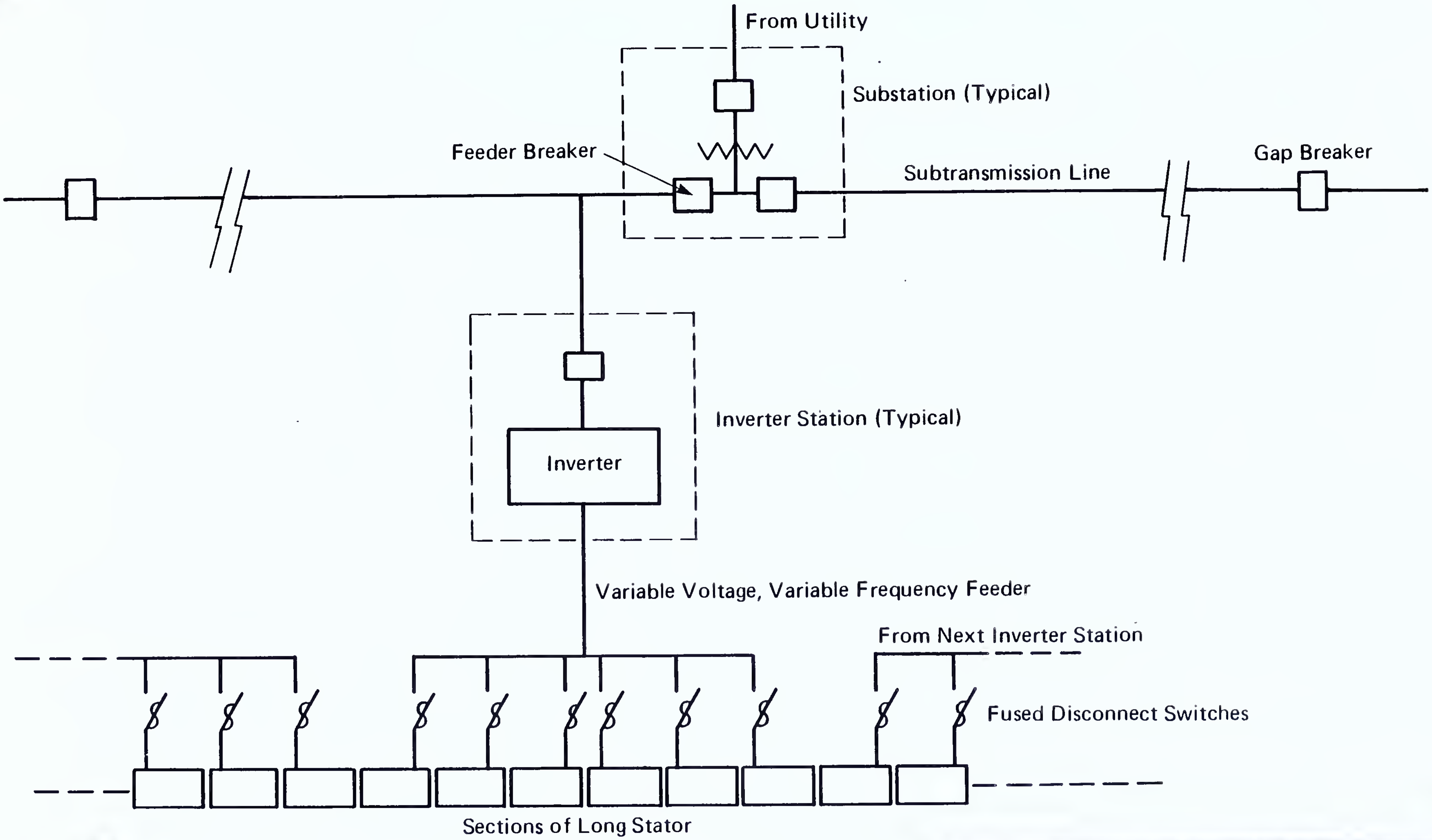

From Utility
Substation (Typical)
Feeder Breaker
Gap Breaker
Subtransmission Line
Inverter Station (Typical)
Inverter
Variable Voltage, Variable Frequency Feeder
From Next Inverter Station
Fused Disconnect Switches
Sections of Long Stator

Figure 7-12

One-Line Diagram–Typical Substation and Typical Inverter Station Alternative E

Within each substation, a transformer will step down the voltage to supply subtransmission lines extending in each direction along the guideway. Tentatively, 38 kV has been selected for the voltage on the subtransmission lines. From each substation, the subtransmission line extends halfway to the next substation to a gap breaker station. In the gap breaker station, a normally-open circuit breaker would be connected to the subtransmission lines from opposite directions.

If there is a loss of power from the utility, or if the substation must be shut down for any reason, the feeder breakers in the substation can be opened, the gap breakers closed, and power remains available on the subtransmission lines.

Inverter stations would be located at intervals varying between about 1.25 and 2 miles. The exact distance between these inverter stations depends on the power level normally required in that section of the guideway.

Each inverter station energizes a variable-voltage, variable-frequency feeder which is extended along the guideway. At intervals of about 1325 ft, sections of the long stator of the propulsion motor are energized from the feeder through fused disconnect switches. Both the voltage and the frequency supplied to the feeder from the inverter are proportional to the speed of the train as it passes through the section of guideway supplied by the inverter. Output from the inverter is supplied only a few moments before a train approaches and is shut off as soon as the train has passed.

The number of sections of the long stator which can be supplied from an inverter station depends on the level of power normally required by a train in the section. For example, with a motor producing 30,000 lbs thrust, only five sections of the long stator can be energized from an inverter; for a motor producing 13,200 lbs thrust, eight sections of the long stator can be energized from the same inverter.

7.4 COMMUNICATIONS AND SIGNALS

By and large, existing communications and signaling systems in the Amtrak/Conrail corridor are adequate only for existing operating speeds and traffic levels. Higher-speed operations will require either upgraded or new signals and possibly a new communication system. Conrail is currently upgrading the signaling system, primarily between Conpitt Junction and Harrisburg, extending its Traffic Control System (TCS) and renewing or replacing interlockings. Signal block lengths, however, are not being designed for higher than present-day speeds.

Under Alternative B, only minor changes are proposed to be made to the existing signal system — mostly adding or extending code lines and/or lengthening crossing protection circuits to permit higher speeds in certain track segments. These changes would require the concurrence of the respective owners/operators of the tracks.

Under Alternative C, new or upgraded signals would be provided throughout in conjunction with the track changes or improvements proposed. It remains to be determined how the signals on new high-speed trackage within the existing Conrail right-of-way would be coordinated with signals on adjacent freight tracks. Certainly at jointly-used interlockings, the systems would have to be directly interconnected, implying joint operation of the system. Conceptually, a system could be designed to accommodate both freight and passenger service on parallel tracks; however, many details remain to be worked out. Communications and signaling under Alternatives C-Electric, D, and E are discussed separately below.

7.4.1 Alternative C-Electric

Signals East of Harrisburg

During this conceptual electrification study, a detailed review of existing signals east of Harrisburg has not been made. Amtrak is continuing to make signaling improvements, but most of the signal apparatus is quite old. FRA requires that signal systems for train operation at 110 mph include cab signals, which are already installed in this corridor. The entire signal system must be examined, however, for adequacy at 110 mph (checking preview distances and safe braking distances) in both the normal and reverse direction of travel to determine what changes would be required. Changes in the signal power system would be needed where new signals are installed to provide stepdown transformers at these locations. Much of the existing signal system would require replacement to permit 110 mph operation.

Signals West of Harrisburg

Signals at locations between Harrisburg and Pittsburgh are older and are also not designed for speeds of 110 mph or for electrification. Conrail has been modernizing the signal system between Harrisburg and Conpitt Junction. The new signals, which include provision for reverse running and a traffic control system, are designed to be suitable for existing freight and low-speed passenger services. Their design does not provide for future electrification of the route.

For the dedicated electrified passenger tracks in the rural areas between Harrisburg and Pittsburgh, a new signal system is needed with appropriate safe braking distance for high-speed passenger service. This signal system must provide cab signaling and permit reverse running. The circuits and apparatus to be used in the new signal system must also be compatible with the new electric traction power system. Because of inductive interference, the signals for freight tracks adjacent to the electrified passenger tracks would also have to be replaced. In urban areas where electrified passenger operations and diesel freight operations might share the same tracks, the signal system would have to be replaced.

Interlockings for High-Speed Passenger Service

To improve the performance of the high-speed passenger service under Alternative C, it would be desirable to construct improved or new interlockings so that trains not making diverging moves could maintain a maximum track speed of 110 mph. With a No. 20 turnout, the highest-speed type regularly produced in the United States, a maximum speed of 45 mph would be permitted for diverging moves. Higher-speed turnouts probably would not be warranted under this alternative.

Two types of new interlockings may be required: a two-track universal interlocking between the eastbound and westbound dedicated passenger service tracks, and a four-track, universal interlocking, connecting tracks normally used for freight service with those used for high-speed passenger services. Both types of interlocking would have to accommodate reverse running on all tracks. Approach signals, home signals, and cut-sections ahead of approach signals would be used on all tracks to provide safe braking distances for all trains.

Communications East of Harrisburg

Under this alternative, existing communications facilities would be retained for both passenger and freight operations. Because of continued joint-track use in urban areas, one train dispatcher would probably control both types of trains. In some locations, where communications facilities might have to be moved because of track/catenary realignment, requiring new construction.

Communications West of Harrisburg

The existing communications facilities in the Conrail corridor west of Harrisburg are not designed to operate in close proximity to an electrified railroad.

Electrification west of Harrisburg would require the installation of new communications cables to replace open wire lines now being used, because these existing lines would be subject to unacceptable electrostatic and electromagnetic induction from the electrification. Changes also would be needed in the system configuration and in the equipment used.

In those areas where new 25-kV/60-Hz electrification is introduced, optical fiber cable would be adopted for the backbone trunk communications system between major operating centers. Channels for voice, control and data would be provided in the backbone trunk portion by the use of Type T1 pulse code modulated carrier. Fiber-optic trunk communications circuits are being installed on the Northeast Corridor and on the Conrail portion of the Pennsylvania Corridor.

7.4.2 Alternative D

Signals West of Harrisburg

A new signal system will be needed for new track in the rural areas from Harrisburg to Pittsburgh and for the dedicated high-speed track in urban areas. No trains in the United States operate at speeds of more than 120 mph, and FRA regulations governing the design and operation of signal systems do not exist for higher speeds. For this preliminary examination of high-speed passenger service, it has been assumed that the FRA would accept a proven signal system for speeds to 160 mph or higher, such as that which has been employed so successfully on the Paris-Southeast line in France.

The proposed new signal system differs in one major respect from those presently in use in the United States. Signal systems for 110 mph in the United States generally use wayside and cab signals. The proposed 160-mph signal system would have only cab signals, because as the French have demonstrated, wayside signals cannot be reliably observed by the engineer at high speeds.

There would be areas where the high-speed passenger service operates on dedicated track adjacent to non-electrified freight tracks, such as between Greensburg and Pittsburgh. Where these non-electrified tracks run near the 60-Hz electrification, the signals for the non-electrified tracks would have to be rebuilt.

Signals East of Harrisburg

Between Paoli and Harrisburg, the high-speed service will operate on dedicated tracks with 60-Hz electrification, in areas currently electrified at 25 Hz. The signals on these 25-Hz electrified tracks would have to be replaced with a design compatible with 60-Hz power.

Communications

A completely new communications system would be necessary under Alternative D. This new system would include telephone communications among wayside locations, circuits for supervision and control of the power system, circuits for Centralized Traffic Control (CTC) and circuits for operation of wayside radio base stations, providing communication with the trains.

The system will consist of a multi-channel trunk along the entire route with different channels dropped and inserted at intervals for connections to local wayside facilities and to the radio base stations. The multi-channel trunk will use fiber-optic circuits that are immune to interference from the traction power system and from nearby utility power systems. Four fibers (two active and two spare) likely would provide enough communications and supervisory control capacity. Other fibers in the cable could be used by others; for example, to provide long-distance public telephone service.

The types of apparatus used for fiber-optic communications are changing very rapidly with advancements in design. Therefore, the equipment to be used on the Pennsylvania Corridor probably would be greatly improved over that now used on the Northeast Corridor and elsewhere.

7.4.3 Alternative E

Communications and Train Control Systems

Communications and train control facilities would be built into the proposed Maglev guideway. A broadband slotted waveguide would provide the trunk circuits used to detect the position of the train; to control the frequency, phase and voltage of the output of the inverter stations; to control the flow of energy to the sections of the long stator of the LSM; and to protect all parts of the system against malfunctions and failures. All key information for supervision and control of the system would be supplied to the central control center.

7.5 STATIONS

The railroad stations in all seven cities on the existing route are owned by Amtrak. Three of these --Harrisburg, Lancaster and Philadelphia -- recently have undergone, or now are undergoing, extensive renovation. All three of these provide now, or will provide when completed, adequate passenger accommodations for the present patronage levels.

The stations in Greensburg and Johnstown are in various states of disrepair. Johnstown appears to have the potential to be revamped into a usable passenger station facility. The station in Greensburg is now vacant. One station, Altoona, is in final design prior to new construction by Amtrak. Examination of the proposed building program indicates adequate space for passenger movement, concessions and parking.

At Pittsburgh, the station situation is unresolved. The present Amtrak station has extremely limited space and facilities. Every effort should be made to reach agreement on a suitable replacement.

7.5.1 Station Improvements

The preceding overview of existing station structures deals only with the existing location or site in each of the seven major cities. As each of the alternative HSR systems was examined, it became evident that the necessary modifications to the stations would vary substantially, depending upon engineering requirements and passenger loads. An eighth station, Paoli, was also added to the original list for cost estimating purposes, as was a ninth station under the State College option.

In all cases, the initial selection of station site is based on using the existing or proposed Amtrak station at each stop. Base case and alternative stations being considered for all locations are shown in the table below:

Location	Base Case Station Site	Alternative Station Sites
Philadelphia	Amtrak 30th Street Station	HSR: Market East Maglev: New station west of existing station
Paoli	Amtrak station	Maglev: New station west of existing commuter station
Lancaster	Pennsylvania Station	Maglev Alternatives: (a) Penn Station (converted) (b) Suburban station Manheim Township
Harrisburg	Pennsylvania Station	None
State College	None	HSR: New station near airport (State College option only)
Altoona	Altoona Transportation Center (under construction)	Maglev: New station at site of present Amtrak trailer
Johnstown	Pennsylvania Station	None
Greensburg	Refurbished historic station	None

Pittsburgh	New Station in refurbished Pennsylvania Station building or in proposed new Amtrak station	HSR: Station Square (ex-P&LE Terminal south bank of the Monongahela)

The following general guidelines were used for preparing capital cost estimates for station improvement or new station construction:

Alternative B

Station refurbishment would be aimed at stabilizing and/or upgrading existing structures and improving their appearance and amenities. Provision would be made for new or improved waiting areas, ticketing, signing, etc. — all relatively low-cost improvements. Also included would be structural work on roofs, walls, and floors; painting; and lighting. The following site-specific improvements are reflected in the capital cost estimate:

30th Street Station	-	Signing, ticketing, waiting area in existing station (lower level)
Paoli	-	Signing, ticketing in existing commuter station
Lancaster	-	Signing, ticketing, waiting area, refurbishment in existing station
Harrisburg	-	Signing, ticketing, waiting area in existing refurbished station
Altoona	-	Signing, ticketing, waiting area in proposed Transportation Center
Johnstown	-	Refurbishment of existing historic station; new signing, ticketing and waiting area
Greensburg	-	Refurbishment and partial opening of existing historic station; new signing, ticketing and waiting area
Pittsburgh	-	New station either in conjunction with proposed new Amtrak station or as part of refurbishment of Pennsylvania Station building

Alternative C

This alternative would provide virtually the highest level of service improvement possible while staying within the existing rail corridor. The electrified version would offer not only trip time and energy source advantages, but also the possibility of running through the recently completed Center City Connection in downtown Philadelphia to the new Market East Station. Renovation work would be much more extensive than under Alternative B and would include high-level station platforms and improved platform access (elevator/escalators for the elderly and handicapped). Additional parking, kiss-and-ride areas and intermodal transfer facilities would also be included. The following site-specific features beyond those listed in Alternative B are included in the estimate:

Market East Station - Signing, ticketing, separate waiting area, parking structure

30th Street Station - Improvements to upper level if electrified option is chosen

Paoli - Addition of high-level platforms, parking

Lancaster - Complete station refurbishment, kiss-and-ride area, added parking

Harrisburg - Addition of high-level platforms, escalators, expanded waiting area

Altoona - Addition of high-level platform and parking

Johnstown - Addition of high-level platform and parking

Greensburg - Addition of high-level platforms, parking, and extensive station rehabilitation

Pittsburgh - Addition of high-level platforms, parking and expanded waiting area

Alternative D

This alternative would provide premium HSR service, equivalent in trip time and passenger amenities to airline service. Station improvements would be similar to those in Alternative C, but would be more extensive — providing larger facilities for high passenger volumes. If the State College or Station Square options are chosen, new stations would have to be provided at those locations.

Alternative E

This alternative would provide the highest possible level of ground transportation service. Station facilities would have to be virtually completely new to accommodate the Maglev option. While the stations under this alternative might be located at, or adjacent to, the sites of existing Amtrak stations, train access facilities (primarily platforms) would be separate and dedicated to Maglev. Site specific guidelines are provided below:

Philadelphia - New Maglev station adjacent to existing Amtrak station at 30th Street (siting and facility criteria must be developed further)

Paoli - New Maglev station west of existing Amtrak commuter station within Amtrak right-of-way. A single island platform is required in vicinity of U.S. Route 30

Lancaster

Downtown - Maglev island platform located in place of existing westbound high-level platform; escalator/elevator access from above; new/rebuilt station structure, parking facilities, etc.

Suburban Station alternative - New aerial station adjacent to, or spanning Oregon Pike (Route 272) in Manheim Township. Parking, kiss-and-ride, bus transfer facilities

Harrisburg - Maglev island platform located in place of one existing low-level platform; escalator/elevator access from above

Altoona - Separate new station and parking facilities adjacent to proposed transportation center

Johnstown - New island platform in place of existing westbound Amtrak platform; escalator/elevator access from below; parking garage; expanded station facilities

Greensburg - New island platform in place of existing westbound Amtrak platform; escalator/elevator access from tunnel under tracks; totally refurbished station; parking and bus transfer facilities

Pittsburgh - New station adjacent to existing Pennsylvania Station; parking, bus transfer facilities

7.5.2 Station Planning Guidelines

In planning station improvement and determining space requirements for new stations, the following guidelines were employed. The base demand estimates, broken down into daily and peak hourly passenger flows in and out of each station, were used in all cases to determine station waiting area and parking requirements.

Station Space: To determine waiting area sizes, the estimated peak hour loading was divided in half to reflect the assumption of two trains in the peak hour, and was reduced by 50 percent again to account for passengers waiting on platforms, in queuing areas and passengers arriving just in time for the train. A factor of 10 square feet per waiting passenger was used in arriving at the required size. Other space requirements were estimated on a station-to-station basis to accommodate ticketing, baggage handling, crew facilities, office space, passenger services, telephones, restrooms, concessions, food service, maintenance and tool room, janitor's closets, machine rooms and so forth. The space estimated for each case was based on the projected activity level at each location under each alternative. Total station area and parking requirements are shown in Table 7-2.

TABLE 7-2

PROJECTED STATION AREA AND PARKING REQUIREMENTS
(Costed Area, sq ft/New parking spaces required)

STATION	Alternative			
	B	C	D	E
Philadelphia	2,240/0	7,650/318	11,200/398	24,720/439
Paoli	1,140/0	2,280/653	3,080/720	6,980/810
Lancaster	1,620/0	3,830/214	4,740/203	7,420/670
Harrisburg	2,500/0	3,250/148	5,300/172	12,200/190
Altoona	800/0	900/240	5,800/420	5,800/420
Johnstown	1,100/0	2,040/300	2,940/540	4,730/540
Greensburg	4,600/0	6,370/840	7,320/923	7,670/953
Pittsburgh	9,520/0	16,745/616	20,945/762	22,945/844

Parking: Parking requirements at major urban area stations (Philadelphia, Harrisburg, Pittsburgh) were estimated by assuming that one-third of the daily rides would require a parking space, and that one-half of those could be accommodated by existing available spaces. (The other two-thirds were assumed to arrive by public transportation, to be dropped off at the station or to arrive in another passenger's car.) Parking at all other stations was calculated by assuming that three-quarters of the daily riders would require a parking space. (At Lancaster, the new parking requirements were reduced by one-half to account for existing spaces available.) New parking structures were assumed to be required at Philadelphia and Pittsburgh. New parking at all other stations was assumed to be provided on surface lots. No new parking was assumed under Alternative B. The number of spaces required in each location is shown in Table 7-2.

Platforms: Under Alternatives C, D, and E, high-level platforms 500 ft in length were assumed to be required for the base case demand. The higher demand scenario would require longer platforms. An escalator and an elevator for the handicapped are planned at each station for platform access.

7.5.3 Alternative Station Sites

During the course of this study, it became apparent that in Philadelphia and Pittsburgh, there were alternative station locations. In Pittsburgh, Station Square could be used to relieve some of the auto traffic and parking demand which a terminal facility would generate in the Golden Triangle.

In Philadelphia, an eastbound high-speed train, after a stop at 30th Street station, could proceed to Suburban Station in Penn Center and on to the new Market East station. These two additional stops would bring the HSR passenger directly into the city's commercial, retail, and governmental heart; moreover, the Market East station serves the city's proposed large-scale convention facilities.

While both these possibilities have been identified, it is beyond the scope of Phase 1 to undertake a detailed comparison. The technical, economic and political implications of changes of such magnitude will be examined in later phases of this study.

7.6 MAINTENANCE FACILITIES

Maintenance requirements will be determined in part by the particular technology selected. Magnetic levitation technology would require a maintenance philosophy that resembles the aircraft industry concept, and would require a level of sophistication that is not presently conventional in the railroad or transit industry in the United States. The maintenance facilities analysis attempts to reflect this difference.

Diesel-electric powered locomotives would be larger in size and weight than the electric and Maglev vehicles. Non-electrified options would need more substantial lifting equipment, overhead cranes, additional storage space and overall building structural systems. Diesel-electric equipment facilities will also require servicing and fueling areas, which are not necessary for the electric and Maglev vehicles. Component changeouts on diesel-electric vehicles would be more cumbersome than on the electric and Maglev vehicles, but repairs would be more conventional in nature. Troubleshooting and diagnostic testing methods must be considered in the development of maintenance facilities, as they greatly affect the basic equipment costs. Based on the relatively small fleet of vehicles proposed for the system, consideration must be given to repairing and overhauling components and assemblies through outside vendors or subcontractors. The amount of repair and overhaul work performed in-house should be based on its cost-effectivness and the availability of skilled technicians.

7.6.1 Vehicle Maintenance Facilities

For purposes of the feasibility study and cost analysis, it is envisioned that the system will contain vehicle maintenance facilities at or near Philadelphia, Johnstown/Altoona and Pittsburgh.

The availability, reliability and dependability of the vehicles for the system will be determined by the performance of the maintenance facilities. Regardless of the type of propulsion system, maintenance activities can be generally grouped into:

- preventive maintenance
- running repair
- cleaning (interior and exterior)
- heavy repair
- overhaul
- support maintenance.

The vehicle maintenance facilities programmed for the Philadelphia and Pittsburgh areas are referred to as service facilities; the central facility proposed for Johnstown/Altoona is referred to as the main shop.

Service Facilities

The service facilities will perform preventive maintenance, running repairs and cleaning. Preventive maintenance includes regularly scheduled blowdown, daily inspections, mileage/time interval inspections and wheel truing.

Blowdown involves the cleaning of motor brushes, commutators, and interior parts to remove carbon buildups; cleaning of filters, contactors, underfloor components and truck assemblies to remove loose dirt and dust; and vacuum cleaning of electronic equipment compartments and assemblies.

Daily inspections will be performed on the vehicles as they leave revenue service and departure tests will be performed on vehicles prior to entering revenue service.

Mileage and time interval inspections might occur at intervals of:

- 15,000 miles or 30 days
- 40,000 miles or 90 days
- 75,000 miles or 180 days.

These inspections would range from a basic safety inspection to light and moderate levels of scheduled system preventive maintenance and could generally be accomplished in one shift or less. Pits or modified versions of pits are required for these inspections. A storage yard will be required at both service facilities.

Wheel truing is critical to maintaining good ride quality and minimizing track damage. A regular cycling of equipment over a wheel truing machine will be required.

Running repairs require a pit and generally take from one to eight hours to perform. Running repairs include repair of vehicle underfloor equipment, interior and rooftop systems, light component changeout, pantograph servicing, and heating and air-conditioning component work. Short-term running repairs (less than one hour) could also be accomplished in the yard.

Cleaning vehicles at both ends of the line will be required to maintain their appearance. Interior and exterior cleaning should be performed on a scheduled basis in off-peak hours.

Main Shop

The main shop would be the central vehicle maintenance facility and provide the base for heavy repairs, overhaul and support maintenance.

Heavy repairs would include mileage/time interval inspections such as:

- 150,000-mile or one-year interval — items from all previous interval inspections plus in-depth preventive maintenance

- 500,000-mile or five-year interval — items from previous interval inspections plus major system and component overhaul.

Heavy repairs include vehicle system repairs, major component changeouts, retrofit changes, and body and paint work. Heavy repairs require the use of equipment such as overhead cranes and lifts.

Vehicle overhaul requires long-term shop spaces and involves many of the requirements described for heavy repairs. Support maintenance includes all the necessary back shops required for vehicle maintenance. Some of the shops required are:

- truck shop — wheel, axle, bearing, and truck repairs and overhaul work
- electrical shop — motor, general wiring and electrical component repair and overhaul
- component rebuild shop — repair of unit exchange items (primarily electronic components)
- machine shop — general machine shop to support the entire facility
- weld shop — overall welding capabilities for the facility
- pantograph repair — pantograph removal and replacement and repair work
- air conditioning shop — repair and overhaul of AC components and assemblies.

The main shop would also require a storage yard for vehicles awaiting service and for repaired vehicles waiting to be returned to service.

7.6.2 Maintenance-of-Way Facilities

The maintenance-of-way function will involve maintaining the fixed physical plant of the HSR system to ensure smooth and safe operation. Maintenance requirements can be generally reduced if planning and foresight are used to develop the overall system design.

Maintenance-of-way facilities are proposed at seven locations spaced at roughly equal distances. These facilities will provide space for storage of materials and parts, personnel facilities, parking and storage of vehicles and equipment. The complex will be secured to discourage trespassers and vandals.

Work to be performed by the maintenance-of-way group would include:

- track or guideway inspections before the commencement of each day's high-speed train operations
- periodic inspections of facilities
- programmed maintenance of signals, communications, electrical, trackwork, structural and mechanical items
- unscheduled (emergency) maintenance and repairs
- snow removal
- station cleaning
- landscaping, right-of-way and grounds maintenance.

References

1 Georges Jacques Janin, "Track Approaching Perfection," Railway Gazette International, September 1981, p. 730. FRA Class 6 track is permitted to have up to 0.5-inch deviations in surface and 0.375-inch deviation (of the mid-ordinate from a 62-foot chord) in line.

2 "Conrail Electrification Feasibility Study," Gibbs & Hill, Inc., November 1979.

CHAPTER 8
COST ESTIMATING

The cost estimating process employed in the HSR feasibility study takes into account a large number of factors to provide thorough consideration of the relationships among the alternative technologies, alternative alignments, and existing rail infrastructure and operations. This chapter presents descriptions of the estimating process, capital cost estimates, operating and maintenance cost estimates, and comparative cost estimate summaries. The resulting cost estimates are based on the infrastructure requirements developed in Chapter 7, and are subject to the assumptions and caveats noted in Chapter 7 and elsewhere in this report.

Detailed cost analyses were performed for final Alternatives C, D and E, and two variants. These alternatives (described in detail in Chapter 4) are listed below:

Alternative	Name and Concept
C	Improved Existing
C-Electric	Improved Existing (fully electrified)
D	High Speed Rail
D-State College	High Speed Rail via State College
E	Maglev

8.1 CAPITAL COST ESTIMATING

Cost estimates have been prepared for both conservative and optimistic demand projections to determine whether the range of possible system costs for each alternative might influence the selection of an alternative for refinement in subsequent phases of the study.

All costs are presented in fourth quarter 1983 dollars. Where historical cost data were used as the basis for an estimated cost, these data were escalated using the Construction Cost Index.[1] Other indices, such as those published by the Bureau of Labor Statistics, were not necessary for this analysis because the majority of costs used were current. Wage rates and mechanical component costs are examples of areas where such indices might have been necessary, but where current data were available.

Capital costs were divided into major elements, or categories, to enable comparison of the costs of each alternative by element and to enable better analysis of the sensitivity of cost categories to operating and alignment assumptions. This also allows a more productive focus in costing efforts of subsequent phases. The infrastructure categories used and major items included are:

- Track/Guideway and Structures — includes the complete track structure for conventional and high-speed rail systems and special purpose guideway for Maglev. Also included are cuts and fills, rail and highway bridges, grade crossing eliminations, tunnels, fencing, new right-of-way acquisitions and easements, as well as any relocation of existing rail facilities and highways to maintain their current level of service without interference from HSR operations.

- Stations — includes station building rehabilitation or new construction, platform construction, parking lots or decks, and elderly and handicapped accommodations. Levels of rehabilitation and station sizes vary by alternative to reflect estimated patronage, condition of the existing station, and amenities to be provided.

- Electric Traction (ET), Communications and Signals (C&S) — includes all components of these subsystems, both central and wayside, as well as required modifications to current facilities. Electric traction components are, of course, provided only for electrically-propelled systems or where track realignments also require the relocation of existing catenary, track circuits or communication links.

- Maintenance Facilities — includes the costs of all building structures, equipment, yard and track, and property acquisition, for both vehicle maintenance and maintenance of way. Emergency vehicles are also included.

- Vehicles — includes the acquisition and testing costs of all passenger vehicles and motive power.

Fleet sizes were determined by analyzing alternative-specific service requirements, as discussed in Chapter 6. These service requirements and demand projections (from Chapter 9) were also used to size the stations and ancillary facilities, as well as to form the basis for the operating and maintenance cost estimates.

A key aspect of the estimating process was that a segment-by-segment calculation of costs was made for track/guideway and structures, C&S and ET under each alternative. This was done to account for known variations in technical requirements in each segment as well as to consider varying operational requirements in a sufficient level of detail for accurate comparison of alternatives. The segments selected are from station to station, resulting in seven segments varying in length from 20 to 132 miles and also varying by alternative to reflect alignment differences. Other cost categories were estimated on a systemwide basis where the costs varied more by alternative than by segment.

Costs include all contractor overhead and profit and assume standard contractor-subcontractor relationships, no acceleration of construction schedule from expected normal productivity rates, and a low-bid award process.

Engineering and construction management costs were added separately as a percentage of the fixed facilities cost estimates. The value used for all alternatives was 18 percent, which reflects extensive contract design and construction coordination between subsystems and with ongoing existing railroad operations, soil boring and route surveying efforts, and construction management. The vehicle estimates include a factor for engineering and testing equal to 10 percent of the base vehicle cost estimates. This value includes preparation of procurement specifications, monitoring of the vendor quality assurance program, and pre-revenue service testing.

Varying construction durations have been established to reflect the financing needs of the alternatives as well as the complexity of the construction process for technologies that have yet to be implemented in the United States. These durations are: Alternative C — 8 years; Alternative D — 10 years; and Alternative E — 12 years. The percentages of capital costs expended per year were calculated using the values reported by the French National Railways (SNCF) in implementing the TGV-Southeast.

The cost estimates developed at this phase of the feasibility study are necessarily based on less than complete information, requiring assumptions to be made. These assumptions affect both the quantities and unit costs used to compute the estimates.

To compensate for the uncertainty caused by imperfect knowledge, contingency factors are applied to the appropriate estimate subtotals. Two types of contingencies are included: a design contingency and a construction contingency. The construction contingency is used to account for unforeseeable costs incurred after contract award, during construction. Items such as hidden rock and relocation of previously unidentified utilities are examples of conditions that might require the use of contingency funds. The construction contingency value used for all fixed facilities is 15 percent.

Design contingency is added to reflect the uncertainties associated with imperfect knowledge of site-specific conditions for the several rail alignments studied. An example of this condition is the possibility that costs to install parallel passenger tracks and realign Conrail freight tracks may exceed the cost allowance provided. These conditions will be known at later phases of the feasibility and design studies, and consequently, the design contingency decreases to zero at the point of construction bid. It is employed at earlier phases of the project to represent an upper limit to the cost growth which could be possible. At this stage of the project, a 25 percent factor has been used to reflect this potential growth for all fixed facilities.

Cost estimates prepared under this process are therefore expressed as a range of costs: the lower cost, representing the cost target, includes a 15 percent contingency only; the higher cost, representing the potential maximum cost at this stage, includes an additional 25 percent contingency amount.

The contingency amounts used in the vehicle cost estimates are 10 percent for Alternative C, 20 percent for Alternative D, and 30 percent for Alternative E, applied to the base vehicle cost plus engineering and testing.

8.1.1 Capital Costs

Capital cost estimates are presented in Tables 8-1 and 8-2. These tables provide total costs by alternative and are broken down by cost category for the base demand scenario (C1, D1, E1), which represent the conservative demand levels.

TABLE 8-1

CAPITAL COST ESTIMATE SUMMARY—Base Demand
1983 Dollars in Millions

Element	Alternative				
	C	C-Electric	D	D-State College	E
Track/Guideway & Structures	$ 997.7	$ 1,051.1	$ 4,646.4	$ 4,671.1	$ 4,30
Stations	31.7	31.7	40.8	45.1	4
Electrification, Communications & Signaling	128.6	325.9	384.1	412.3	2,67
Maintenance Facilities	50.2	55.5	61.8	61.8	10
Subtotal 1	$ 1,208.3	$ 1,464.2	$ 5,133.1	$ 5,190.3	$ 7,13
Engineering & Construction Management @ 18%	217.5	263.6	924.0	934.3	1,28
Subtotal 2	$ 1,425.8	$ 1,727.8	$ 6,057.1	$ 6,124.6	$ 8,42
Contingency @ 15%	213.9	259.2	908.6	918.7	1,26
Subtotal 3	$ 1,639.7	$ 1,987.0	$ 6,965.7	$ 7,043.3	$ 9,68
Vehicles (Including Test @ 10% & Contingency)	205.2	216.8	203.3	203.3	33
Target Cost Estimate	$ 1,844.9	$ 2,203.8	$ 7,169.0	$ 7,246.6	$ 10,02
Additional Contingency @ 25% of Subtotal 2	356.4	432.0	1,514.3	1,531.2	2,10
Maximum Cost Estimate	$ 2,201.3	$ 2,635.8	$ 8,683.3	$ 8,777.8	$ 12,12

TABLE 8-2

CAPITAL COST ESTIMATES BY COMPONENT
Base Demand
(1983 Dollars in Millions)

Item	Alternative				
	C	C-Electric	D	D-State College	E
Track/Guideway & Structures:					
o New Track	$ 399.2	$ 399.2	$ 721.2	$ 721.4	$ -
o Rehabilitate/Relocate Track	188.1	188.1	119.5	133.6	30.7
o Bridge/Crossing Modifications	77.5	130.9	1,638.0	1,406.4	48.5
o Guideway/Switches	-	-	-	-	1,871.9
o ROW Easement & Fencing	18.1	18.1	73.8	77.2	50.2
o Route Realignments	294.0	294.0	-	50.9	-
o Cuts & Highway Relocation	-	-	1,533.1	1,316.8	1,622.8
o Tunnels	20.8	20.8	560.8	964.8	680.1
	997.7	1,051.1	4,646.4	4,671.1	4,304.2
Stations:					
o Philadelphia	$ 3.0	$ 3.0	$ 5.5	$ 5.5	$ 9.8
o Paoli	4.6	4.6	6.7	6.7	6.8
o Lancaster	1.8	1.8	1.8	1.8	2.4
o Harrisburg	.6	.6	.8	.8	2.4
o State College	-	-	-	4.3	-
o Altoona	3.6	3.6	4.5	4.5	4.4
o Johnstown	3.1	3.1	4.3	4.3	4.4
o Greensburg	6.2	6.2	6.7	6.7	6.9
o Pittsburgh	8.8	8.8	10.5	10.5	11.5
	31.7	31.7	40.8	45.1	48.6
Electric Traction/Signals & Communications:					
o New Catenary/Electrification	$ -	$ 83.9	$ 107.5	$ 115.1	$ 2,666.7
o Adjust Catenary	10.1	12.4	10.9	10.9	1.3
o Install New C & S	86.3	84.8	196.3	214.2	-
o Modify Signals	18.1	90.2	12.1	12.2	
o Route Realignment C & S	9.5	9.5	-	-	-
o Central/Section Control	4.6	5.6	7.3	7.3	10.2
o Substations	-	39.5	50.0	52.6	-
	128.6	325.9	384.1	412.3	2,678.2
Maintenance Facilities:					
o Main Shop & Yard	$ 14.6	$ 15.0	$ 17.6	$ 17.6	$ 32.1
o Line Shop & Track	12.8	13.7	15.3	15.3	26.6
o Maintenance-of-Way	20.9	24.4	26.5	26.5	44.4
o Property Acquisition	1.4	1.4	1.4	1.4	1.4
o Systemwide Equipment	.5	1.0	1.0	1.0	1.0
	50.2	55.5	61.8	61.8	105.5
Vehicles:	$ -	$ -	$ 154.0	$ 154.0	$ 237.6
o Locomotives	54.4	64.0			
o Coaches	115.2	115.2	-	-	-
	169.6	179.2	154.0	154.0	237.6

Additional demand analyses were conducted for more optimistic levels of demand, as discussed in Chapter 9. The capital costs were reviewed in light of the higher demand. Track/guideway and structures cost, ET/C&S costs and maintenance facility costs were assumed to be unaffected by the different demand scenarios. Stations were sized, in both cases, for the base demand values. Under the high-demand scenario, the fleet size was increased, but not in direct proportion to the growth in ridership. This reflects the fact that a system would probably not initially procure a vehicle fleet based on the high end of the demand projection range. Also, scheduling modifications might be possible to reduce the peak load factors. Capital cost estimates under the high demand scenario (C3, D3, E2) are identical to the estimates under the base demand scenario except for vehicles as shown in Table 8-3.

Construction budgets, by year, for the base demand scenario are provided in Table 8-4.

The costs for the high demand scenario are assumed to be spread using the same percentages of total system costs which marginally increases yearly expeditures.

Replacement of capital items during the 30-year analysis period is assumed to be limited to vehicles. The cost of a new fleet of vehicles has been added in the 16th year of full system operation. All other component replacement costs (ties, rail, signals and so forth) are included in the O&M material costs, and no complete subsystem replacements are assumed to be required.

8.2 OPERATING AND MAINTENANCE COST ESTIMATING

As with capital costs, operating and maintenance (O&M) costs were divided into categories for ease of comparison and for a logical calculation and presentation. The categories and descriptions are as follows:

- Track/Guideway and Structures — includes all labor and materials necessary to maintain track or guideway and associated structures.
- Electrification Maintenance — includes labor and materials necessary to maintain all wayside equipment and catenary, substations, and high-voltage lines to the primary power source. Maintenance of central power "mimic boards" is also included.
- Vehicle Maintenance — includes all labor and materials for scheduled vehicle inspections, maintenance, cleaning, repair of failed components, and overhaul.
- Station Operations and Maintenance — includes labor and materials necessary to maintain the station structure and platforms and provide for all station operations. Ancillary parking lot and structure O&M expenses have been assumed to be offset equally by parking revenues.
- Signals and Communication Maintenance — includes all labor and materials required to maintain wayside signals and communication links as well as central control equipment. For the Maglev alternative, the maintenance of electrification, signals and communications are combined due to the nature of the system.

TABLE 8-3

CAPITAL COST ESTIMATE SUMMARY—High Demand
1983 Dollars in Millions

Element	Alternative				
	C	C-Electric	D	D-State College	E
Subtotal 3 from Table 8-1 (excluding vehicles)	$ 1,639.7	$ 1,987.0	$ 6,965.7	$ 7,043.3	$ 9,684.3
Vehicles (Including Test @ 10% & Contingency)	243.7	257.4	246.8	246.8	396.4
Target Cost Estimate	$ 1,883.4	$ 2,244.4	$ 7,212.5	$ 7,290.1	$ 10,080.7
Additional Contingency @ 25% (of Subtotal 2 from Table 8-1)	356.5	432.0	1,514.3	1,531.2	2,105.3
Maximum Cost Estimate	$ 2,239.9	$ 2,676.4	$ 8,726.8	$ 8,821.3	$ 12,186.0

TABLE 8-4

CAPITAL COSTS - CONSTRUCTION STAGING
Base Demand - 1983 Dollars in Millions

Year	C	C-Electric	D	D-State College	E
1987	$ 18.8	$ 22.5	$ 21.5	$ 21.8	$ 29.1
1988	84.5	100.9	52.3	52.9	73.2
1989	279.1	333.4	328.3	331.9	459.1
1990	350.9	419.1	824.5	833.4	1,052.6
1991	416.8	497.9	1,057.4	1,068.8	1,052.6
1992	372.1	444.5	1,208.0	1,221.0	1,122.7
1993	217.3	259.6	1,215.1	1,228.3	1,152.8
1994	105.4	125.9	1,208.0	1,221.0	1,152.8
1995			844.6	853.6	1,152.8
1996			409.3	413.9	1,152.8
1997					1,052.6
1998					571.0
Total	$ 1,844.9	$ 2,203.8	$ 7,169.0	$ 7,246.6	$ 10,024.1

- o Train Operations — includes the cost of vehicle power (electricity or fuel) and train, engine and food service personnel.
- o Central Operations and Administration — includes the cost of personnel for operations, scheduling, administration and security; and administrative material and purchased services (e.g., telephones and insurance).

Wage rates are based on average railroad and airline industry rates for 1983 as reported to the Interstate Commerce Commission (Report A-300) and the International Civil Aviation Organization (Form D-1), respectively. Direct labor rates were increased by 35 percent to include fringe benefits. The number of crews necessary for each alternative were based on existing industry practices modified as necessary to reflect the unique operating requirements of each alternative. Also, the specific labor skills costed for each alternative reflect the technological differences between the alternatives. This results in a marginally higher average cost per employee as the level of technology increased.

Materials and purchased service costs have been based on industry averages for each cost category. These averages were modified to reflect specific HSR operating characteristics and new technology requirements.

8.2.1 Operating and Maintenance Costs

Tables 8-5 and 8-6 provide the O&M cost estimates for full system operation for base and high demand projections, respectively. Staff sizes and material requirements were varied to reflect the differences in patronage.

8.3 DETAILED CAPITAL COST DEVELOPMENT

8.3.1 Track/Guideway and Structures

The capital costs for new track, track improvements and structures were developed by building a base price from the material prices indicated in Table 8-7 to develop work item unit costs as shown in Table 8-8. Work-around requirements were then determined and added to the developed base prices on a segment and alternative/technology basis, as appropriate. Quantities were then calculated or, in some instances, selected on an allowance basis where detailed locational information was unavailable or where conflicting data was encountered.

New Trackwork

Trackwork for improving existing service was estimated on the basis of 132 pound continuous welded rail, wood ties, spike fastening system, ballast, filter fabric, and other track material, for a total base cost of $120.63 per track foot. For the new HSR trackwork, concrete ties and spring clip fasteners were used. This increased the base cost to $140.00 per track foot. Where applicable, track removal was added at $13.35/linear foot and applied to these base-cost figures.

TABLE 8-5

O&M COSTS—Base Demand
1983 Dollars in Millions

Item	Alternative			
	C	C-Electric	D	E
Track/Structures				
Labor	$ 15.64	$ 15.64	$ 19.78	$ 21.07
Material	15.24	15.24	15.40	12.89
Electrical Maintenance				
Labor	--	5.86	6.60	32.77
Material	--	2.77	3.08	21.49
Vehicle Maintenance				
Labor	17.73	9.57	15.84	11.64
Material	8.82	4.68	8.77	8.61
Station Operation & Maintenance				
Labor	5.92	5.92	6.95	9.91
Material	1.00	1.00	1.20	1.50
Signals & Communications Maintenance				
Labor	7.84	7.84	6.60	(Incl. in Elect.)
Material	2.77	2.77	3.70	
Train Operations				
Vehicle Crew	9.81	8.19	9.55	8.69
Power	8.17	10.98	11.41	18.74
Central Operations & Administration				
Operations Schedule	1.55	1.55	1.55	1.55
Administration	3.89	3.68	4.44	5.44
Material & Services	6.09	5.93	5.91	7.91
Insurance	1.71	1.71	1.97	2.43
Security	1.44	1.44	1.44	1.44
TOTAL	$107.62	$104.77	$124.19	$166.19

TABLE 8-6

O&M COSTS—High Demand
1983 Dollars in Millions

Item	Alternative			
	C	C-Electric	D	E
Track/Structures				
Labor	$ 15.64	$ 15.64	$ 19.78	$ 21.07
Material	16.51	16.51	17.42	13.84
Electrical Maintenance				
Labor	--	5.86	6.60	32.77
Material	--	2.77	3.08	21.49
Vehicle Maintenance				
Labor	21.06	11.37	19.20	13.57
Material	13.54	9.13	13.45	12.64
Station Operation & Maintenance				
Labor	14.10	14.10	15.38	20.64
Material	1.00	1.00	1.20	1.50
Signals & Communications Maintenance				
Labor	7.84	7.84	6.60	(Incl. in Elect.)
Material	2.77	2.77	3.70	
Train Operations				
Vehicle Crew	14.85	12.38	14.14	12.47
Power	12.51	16.81	17.50	27.52
Central Operations & Administration				
Operations Schedule	1.55	1.55	1.55	1.55
Administration	5.37	4.61	5.47	6.47
Material & Services	8.45	7.67	7.54	9.60
Insurance	4.07	4.07	4.36	5.07
Security	1.44	1.44	1.44	1.44
TOTAL	$140.70	$135.52	$158.41	$201.64

TABLE 8-7

MATERIAL PRICES

Material Item	Unit	Unit Prices (1983 Dollars)
Rail	Ton	$ 472.00
Concrete Ties	Each	72.00
Other Track Material (OTM) for Concrete Ties:		
Shoulders	Each	2.00
E-Clip	Each	1.75
Insulators	Each	1.50
Pads	Each	.85
Wood Ties	Each	38.00
OTM for Wood Ties:		
Plates	Each	7.87
Anchors	Each	2.00
Spikes	Each	.42
Ballast	Cu yd	18.00
Subballast	Cu yd	16.00
Filter Fabric (16 oz)	Sq yd	2.00
Fencing	Lin ft	15.00
Field Welds	Each	325.00
Substation Equipment:		
Incoming Line (230 kV)	Each	162,000.00
High-Voltage Bus (230 kV)	Each	200,000.00
Main Transformer (230 kV/25 kV, Single-Phase, 15 MVA, 5%)	Each	273,300.00
Two-Pole Isolating Breaker (25 kV)	Each	131,250.00
Potential Transformer (25 kV/120 V)	Each	25,000.00
Auxiliary Transformer (25 kV/120-240 V, 167 kVA)	Each	25,000.00
Bus Tie Breaker (25 kV)	Each	168,800.00
Feeder Breaker (25 kV)	Each	106,250.00
Relaying, Control, and Supervisory Control	Lump Sum	343,800.00

TABLE 8–8

WORK ITEM UNIT COSTS

Work Item	Unit	Unit Prices (1983 Dollars)
Clear and Grub	Acre	$ 2,900
Cut:		
20% Rock	CY	4.00
70% Rock	CY	8.00
Subgrade Preparation	TF	52.00
Complete Undercutting and Cleaning	TF	15.00
Gauge and Surface	TF	5.00
Remove Existing Track	LF	13.25
Right-of-Way Preparation	TF	15.00
Turnouts (New):		
No. 15s	Each	90,000
No. 20s	Each	110,000
Turnouts (Rehabilitate):		
No. 15s	Each	45,000
No. 20s	Each	55,000
Single-Track Bridge	LF	3,000
Double-Track Bridge	LF	6,000
Highway Bridge (2-Lane)	LF	2,700
Highway Bridge (4-Lane)	LF	5,400
Pedestrian Access Structures	Each	31,250
Grade Crossing Elimination	Each	800,000
Private Crossing (Culvert)	Each	65,000
Tunnel 20-Foot Diameter Twin Bores	LF	16,000
Tunnel (Cut-and-Cover), Single	LF	8,000
Duck-Unders	Each	5,000,000
Tunnel - Twin Bore (Maglev)	LF	24,000
Tunnel - Cut-and-Cover (Maglev), Single	LF	12,000
Guideway - At-Grade:		
Constrained Alignment	Gdwy Mile	3,375,000
Non-Constrained Alignment	Gdwy Mile	2,250,000
Guideway - Double, Elevated:		
Constrained Alignment	Gdwy Mile	5,700,000
Non-Constrained Alignment	Gdwy Mile	5,400,000
Guideway - Double, Elevated (RR Right-of-Way):		8,550,000
Flyovers:		
Double Commuter Traffic		9,190,000
Double Light Traffic		8,100,000
Realigned Catenary on Existing Structures	Track Mile	65,000
Realigned Catenary on New Structures	Track Mile	217,000
New Signals	Track Mile	163,000
Relocated Signal Circuits	Track Mile	110,000
New Catenary and Structure (West of Harrisburg)	Track Mile	204,000
Communications System	Track Mile	169,000
Modified Signals on Adjacent Freight Tracks	Track Mile	142,000
Voltage/Frequency Change Point	Each	100,000
Reinsulated Catenary in Lancaster and Harrisburg	Track Mile	75,000
New Catenary and Structures (Newly Electrified Areas)	Track Mile	185,000
Signals for High Speed Service Paoli-Pittsburgh	Track Mile	210,000
Electrification (Maglev) Includes Signals & Comm.	Gdwy Mile	4,355,000
Substations (15 MVA)	Each	2,620,000

Track Renewal

Renewal of existing trackwork was assumed to involve the replacement of two ties every 39 feet, including plates and spikes; 50 percent rail replacement with surfacing and gauging; and undercutting and cleaning, as necessary. Total base cost for track renewal was estimated at $39.00 per track foot with segment work-around requirements being applied to the base cost.

Turnouts

Installation of new turnouts (switches) was estimated at a unit cost of $90,000 for a Number 15 turnout, and $110,000 (switches) for a Number 20 turnout. Turnout renewal work was judged to cost 50 percent of a new turnout, and includes removal and relocation of the turnout.

Curve and Route Realignments

Realignments were considered in two separate categories, curve and route. Curve realignments having fewer work items were estimated on an individual basis but were aggregated on a segment basis and expressed as a lump sum on the quantity/cost estimating sheets. The route realignments were estimated and listed on the quantity/cost estimating sheets on an individual basis. Included and applied as required in all lump sum costs were earthwork, trackbed preparation, track shift and renewal, structures, electrification, highway relocations, and right-of-way acquisition. Items such as new trackwork and signaling are included in the base estimates for those items as are the specific work-around requirements.

Bridges

Estimating the capital cost of the overhead and undergrade bridge work was accomplished by reviewing each segment/alternative and making judgments on the percentage of bridge modification or replacement work that would be required. Unit costs for work of similar type bridges were then developed separately and estimated on a linear foot basis considering width or number of tracks.

Additional cost factors such as work-around and demolition were considered and applied to the developed unit costs. Work-around percentages costs were judged and varied between segment/alternative; however, a constant factor of 10 percent was added to the base unit costs to account for all demolition work of existing bridge components.

Bridges not considered for modification or replacement were assumed to require no repair work.

Tunnels

Tunnels were considered in two separate categories: bored, and cut-and-cover. Tunnel quantities were estimated on a segment basis, with additional factors being applied for the alignment/technology being considered.

Capital costs associated with tunneling are directly dependent on the type of geological conditions encountered. For the purposes of this estimate, it was assumed that rock, for the most part, would be encountered.

Unit costs of $16,000 per linear foot were used for each of the side-by-side 20-foot diameter rock tunnels. The unit cost was obtained from recently published bid cost information provided by Engineering News Record (ENR). Unit costs of $5,800 per linear foot for cut-and-cover type tunnels up to 30 feet in depth were obtained from recently designed projects and escalated to 1983 dollars using the ENR Construction Cost Index. The costs were further escalated approximately 40 percent to $8,000 per linear foot to account for the expected rock excavation.

Tunneling for the Maglev alternative was assumed to increase the unit cost by 50 percent to allow for the larger required openings (25-foot diameter) and proportionately larger excavation volume.

Grade Crossing Eliminations

Capital costs associated with crossing eliminations were obtained from the ongoing Amtrak NECIP. These crossing eliminations cost approximately $1 million each. In comparing the two projects, it was judged that $800,000 each would be adequate to complete highway and rail modifications in the Pennsylvania Corridor.

Additional costs associated with existing grade-crossing protection circuit removal are included in the ET/C&S costs.

Guideway

Guideway capital costs for the Maglev alternative were developed assuming the use of precast, prestressed, concrete box girders with top flange overhang elevated above grade on concrete pylons. Girders were assumed to be simply supported with 100-to 120-foot-long spans. The average elevation of the girder bottom was assumed to be 30 feet with a maximum of 100 feet. Structures more than 50 ft high were estimated separately as "special structures".

A preliminary guideway design was prepared and served as the basis for cost estimating. Quantities of concrete, reinforcing steel, prestressing tendons, and other miscellaneous materials were estimated. An at-grade design costing 75 percent of the elevated guideway was also developed.

Fencing

The cost for providing fencing was based on recent bid prices and costed on a per-linear-foot basis at $14.25 with additional allowances being added to include pedestrian and vehicular gates. These allowances bring the base price of fencing to $15.00 per linear foot for providing a 7-foot chain-link fence installed with top and bottom wires and line posts on 10-foot centers.

The quantity of fencing was estimated on a percentage basis by alternative/segment with additional variable costs being applied by alternative/segment for anticipated work-around requirements. Alternatives D and E are completely fenced except where the track or guideway is elevated or in tunnel.

Right-of-Way

The cost for right-of-way needed for each alignment was estimated, and land use was categorized as follows: agricultural, wooded/mountainous, commercial, and industrial.

Unit costs were determined by contacting real estate brokers in several locations throughout the state as well as key county assessors' offices. No additional costs were included for dwellings, commercial or industrial structures or other man-made features, because the alignments will, for the most part, follow the existing alignment or pass through unimproved agricultural, wooded or mountainous terrain.

The costs of right-of-way were accumulated on an alternative/segment basis employing the following assumptions or conventions:

1. Adding tracks in a typical section will not require any additional right-of-way.
2. Five percent of the existing route was assumed to be widened to accommodate areas where the existing right-of-way may not be sufficient to permit additional trackage.
3. Right-of-way acquisition for curve realignments, grade crossing eliminations and other improvements is included in the cost summaries of those various improvements.
4. Right-of-way requirements vary between 50 and 120 feet depending on the alternative/segment, with a 10 percent allowance for access made on some alternatives.

8.3.2 Electric Traction, Communications and Signals

Capital costs for the electrification and communications/signals were developed from material prepared in this study. This material examined the requirements for traction power substations, catenary, catenary structures, signals and communications for each alternative/technology being considered. In addition, the wayside propulsion, levitation and guidance equipment, collision protection and communications for a magnetic levitation system have also been examined. The costs developed for work items within the segments vary by alternative due to the existing conditions within the corridor. The unit costs used are consistent with those prepared for previous Conrail electrification proposals.

In estimating the quantities within each segment/alternative, considerable attention was given to the existing features and all quantities and costs were developed accordingly. All work item cost estimates associated with catenary, signals and communications are indicated in Table 8-8. Additional costs were included beyond the indicated work item costs for signals and electrification work associated with turnout replacement. These costs varied by turnout size and were estimated at 50 percent of the costs for providing new turnouts. Grade crossing signal eliminations were estimated to cost approximately $50,000 each, and replacement of existing signals was priced at 25 percent of signal modification costs. Electric traction, signals and communications within all curve and route realignments were included in the base estimates rather than considering them as related to the realignments.

Finally, estimates were prepared for each alternative for central control, sector control and reservations equipment. These estimates vary by alternative between $4.6 million and $10.2 million and are based on technology requirements and operational complexity of each alternative.

8.3.3 Stations

Capital costs for station improvements are based on current station condition. The cost estimates for each station were developed separately using costs associated with minor, moderate and major renovation work. These costs were developed from estimates and bid prices from recently designed, bid or constructed station projects that were similar in nature. The price range of estimates developed vary from $75 to $159 per square foot for renovation work to $192 per square foot for new station construction.

Quantities developed for each station (as discussed in Chapter 7) were based on existing station areas plus additional station and parking areas required to handle projected passenger demand loads for each alternative. Special considerations were given to those stations that have undergone or are now undergoing extensive renovation.

Estimated quantitites and cost items for all stations consisted of structural and architectural renovation work of the buildings and their electrical, plumbing, heating, and air conditioning requirements. Other costs were developed for platforms, vertical circulation (which includes elderly and handicapped access costs) and property acquisition. Additional allowances were included for closed circuit TV and ticketing and reservations equipment. Structural and at-grade parking requirements for each station were developed based on the projected passenger demand loads for each alternative and were estimated at $3,600 per at-grade space and $6,000 per space for structured parking.

8.3.4 Maintenance Facilities

Capital costs for maintenance facilities were based on judgments that the system will contain three vehicle maintenance facilities — two service facilities, and one main shop — each containing a storage yard.

Maintenance-of-way facility requirements were judged to be located at seven locations, roughly equally spaced along the line.

All costs developed for the facilities take in account considerations for building construction, equipment, track, signals, property and site work, which includes fencing and parking. Additional considerations were made within the estimates for the possible rehabilitation and use of a portion of the Conrail Altoona complex for the main shop.

Maintenance facility unit costs are provided in Table 8-9. The cost variations among alternatives are based on differences in maintenance operations and

TABLE 8-9

MAINTENANCE FACILITY UNIT COSTS
(1983 Dollars)

Item	Alternative			
	C	C-Electric	D	E
Main Shop and Yard:				
- Building/sq ft	$ 110	$ 120	$ 140	$ 150
- Equipment/sq ft	60	48	75	80
- Property/acre	50,000	50,000	50,000	50,000
Line Maintenance:				
- Building/sq ft	$ 110	$ 120	$ 140	$ 150
- Equipment/sq ft	15	48	38	20
- Property/acre	50,000	50,000	50,000	50,000
Maintenance-of-Way:				
- Building/sq ft	$ 80	$ 80	$ 80	$ 80
- Equipment/lump sum	1,000,000	1,250,000	1,500,000	2,500,000
- Property/acre	27,000	27,000	27,000	27,000

TABLE 8-10

VEHICLE UNIT COSTS
(1983 Dollars)

Item	Alternative			
	C	C-Electric	D	E
Locomotive	$1,700,000	$2,000,000	$ -	$ -
Coach	1,200,000	1,200,000	-	-
Trainset	-	-	11,000,000	-
Maglev Vehicle	-	-	-	3,300,000

maintenance equipment requirements. The estimates reflect current maintenance facility construction costs for maintenance facilities in comparable geographic areas (excluding metropolitan New York City) modified by the level of maintenance to be performed. Much of the heavy maintenance typically performed in such shops has been assumed to be performed by others and has been included as purchased services in materials expense.

8.3.5 Vehicles

Vehicle capital costs have been estimated based on supplier or developer costs in 1983 dollars. Each alternative was reviewed and train configurations were estimated based on the projected passenger demand and load factor assumptions.

Fleet sizes were computed as discussed in Chapter 6. The unit costs shown in Table 8-10 were used in estimating total vehicle costs by alternative.

8.4 DETAILED O&M COST DEVELOPMENT

8.4.1 Train Operations

Train operation costs include labor costs for on-board crews (engineers, conductors, ticket collectors, attendants) and energy costs for motive power (fuel or electricity).

Personnel requirements have been based on train length, patronage levels, and service amenities. The following crew sizes and average annual costs per person reflect the above factors and the technology of the alternative:

C	6-person crew @ $45,000/person
C-Electric	5-person crew @ $45,000/person
D	7-person crew @ $45,900/person
E	7-person crew @ $49,100/person

Energy consumption was estimated using the TPM for each alignment/technology alternative, using actual tractive effort curves for each propulsion type. These energy requirements were then costed at $1.17 per gallon for diesel fuel, which represents the current purchase price (excluding any federal or state use taxes related to highways), and $0.06 per kilowatt-hour for electricity, which reflects average costs across Pennsylvania for purchase at primary rates recognizing the peak nature of the systems and assuming significant power factor correction.

8.4.2 Central Operations and Administration

Several diverse, system-level costs are included in this category and reflect the "corporate" level costs of operating the system. Variations of costs among the alternatives are primarily related to the number of people required and the level of other operating and maintenance costs.

Operations and scheduling costs are those for personnel necessary to staff train control and power supply consoles, communications consoles, information displays, and central security monitors as well as service scheduling. The number of personnel for these functions was assumed to be the same for all alternatives (45 for two-shift operation) at an average annual cost of $34,400 per person. This average cost was applied to all personnel in the central administrative area.

Administrative costs include those for employees in the system manager's office, as well as for personnel, purchasing, accounting, engineering, legal, payroll, and marketing. For this analysis, it was assumed that the administrative staff would be 7 percent of the total complement.

The materials and services cost category includes the costs of all stationery, supplies, and other consumables required for central operations and administration; purchased services such as phone systems, copiers, and computers; as well as facility lease costs. These costs were assumed to total 6 percent of all other O&M costs for the C alternatives and 5 percent for the D and E alternatives.

Insurance costs were based on the number of passenger-miles estimated for the system. Public liability and property damage coverages are included and were estimated at $0.002 per passenger-mile and reflect transit industry experience.

Security costs are for field personnel and assume two guards per station and two guards per 30 miles of route, plus an additional 10 percent for supervision, resulting in 42 persons for each alternative at an average annual cost of $34,400 per person.

8.4.3 Track/Guideway and Structures Maintenance

Maintenance cost estimates for the track/guideway and structures for the several alternatives have taken into consideration their relative speeds and equipment loads as well as the level of technology. Maintaining the close tolerances required for passenger ride comfort also reduces overall wear on the track structure and tends to lower component replacement costs. The labor and material costs are based on a high level of inspection and preventive maintenance.

Labor costs are based on current rail industry wage rates and work rules for maintenance-of-way employees. Alternative C uses 0.8 persons per track-mile, based on current Amtrak and Conrail experience, while the D and E Alternatives were estimated at 0.9 persons per track-mile. The 0.9 value reflects a higher level of inspection and preventive maintenance for the higher-speed systems. Personnel rates of $35,300 per year for C, $35,700 for D, and $38,100 for E reflect the technology differences of the alternatives. These values are the same for both the base and high-demand scenarios.

Material costs reflect the basic maintenance philosophy and the train/vehicle loads imposed on the track structure. The Alternative C estimates, using lightweight conventional equipment, are $27,500 per track-mile per year. For Alternative D, using concrete ties and lightweight vehicles, the value is $25,000. The Maglev alternative value is estimated to be $21,000 which reflects lower parts usage because of minimal structure wear.

In order to reflect the additional track/guideway use of the high-demand scenarios, an additional $0.03 per vehicle-mile was added to the material costs of each alternative.

8.4.4 Electrification Maintenance

Catenary and substation maintenance for the conventional and high-speed systems (C and D, respectively) have been assumed to require the same number of persons per track-mile, 0.3. Based on industry averages, the annual cost per person is $35,300 for C and $35,700 for D.

Maintenance for the Maglev alternative electrification has been costed to include signals and communications maintenance because of the inductive, non-contacting nature of each of the subsystems. The combined personnel requirements are 1.4 persons per guideway mile at an annual cost of $38,100.

Maintenance material costs are estimated to be $5,000 per track-mile per year for both C and D alternatives. For Maglev, combining electrification, signals and communications materials, the estimated cost is $35,000 per guideway-mile per year. No costs are included for snow melting or deicing of these elements.

Costs for power consumed are included under train operations in subsection 8.4.1.

8.4.5 Signals and Communications Maintenance

Estimates of the costs of maintaining the signals and communications systems are based on rail industry experience applied to the alternatives and operating scenarios. Signals and communications maintenance costs for Alternative E have been described previously and are included in electrical system maintenance costs.

Labor costs for the Improved-Existing and HSR alternatives are different because of differences in the design of the systems. Conventional wayside and cab signal systems are used on Alternative C while cab signals only are used on D. Also, hard wired communication links are used for C while a multi-channel trunk fiber-optic communication system is employed for D. Personnel requirements were estimated to be 0.4 persons per track-mile for C and 0.3 for D. Average per-person costs are $35,000 per year for C and $35,700 for D.

Material costs have been estimated at $5,000 per track-mile per year for the C alternatives and $6,000 per year for D.

8.4.6 Station Operations and Maintenance

Labor and material costs for the operation and maintenance of stations were assumed to be dependent on the passenger demand. Demand level was used to size the queuing, circulation, and platform areas of each station for each alternative. Average wage rates for station personnel for all alternatives was $34,400 per person per year. The number of personnel per station was estimated at 21.5 for the C alternatives, 25.25 for D, and 36 for E, on an average basis for the base demand scenario. The high-demand-scenario values were 51.25, 55.89, and 75 average persons per station for the C, D and E alternatives, respectively.

Material costs represent the purchased janitorial service costs for the station areas for each alternative. The value used in all cases was $10 per square foot per year for both demand scenarios.

As previously mentioned, the operating and maintenance costs of the parking lots and structures have been assumed to be equally offset by parking revenues. Neither costs nor revenues are therefore included.

8.4.7 Vehicle Maintenance

Vehicle maintenance requirements vary for the four alternatives. Both labor and material components of the costs have been modified to reflect these inherent differences.

The labor component of costs was estimated by the number of persons per vehicle in the fleet. The C alternative estimate is 3.7 persons per vehicle, C-Electric is 2.0 persons per vehicle, D is 2.3 persons per vehicle, and E is 4.0 persons per vehicle. The C alternatives reflect current rail industry experience, while the D alternative reflects a slightly higher component for increased inspections and the E alternative assumes the need for a hybrid rail/aircraft maintenance strategy that recognizes the very high speeds and close vehicle/guideway tolerances required for safety and passenger ride comfort. Personnel costs also vary: C alternatives -- $37,400 per person per year, D — $37,800, and E -- $40,400.

Material costs were estimated on a per-vehicle-mile basis for each alternative and were based on current conventional and high-speed rail experience, and on estimates of requirements for the Maglev alternative. The values are as follows:

C	$0.32/vehicle-mile
C-Electric	$0.17/vehicle-mile
D	$0.20/vehicle-mile
E	$0.40/vehicle-mile

There are no differences in the unit costs for any of the alternatives between the base and high-demand scenarios. Cost differences are reflected in the number of vehicles required for each scenario and the number of vehicle-miles traveled by the vehicle fleet.

References

1 Engineering News Record (ENR), Construction Cost Index. Building Construction Cost Data (1983), by R.C. Means Co., Inc. was used as another source.

CHAPTER 9
TRANSPORTATION DEMAND ESTIMATES

9.1 DEMAND ESTIMATING METHODOLOGY

The methodology employed produces patronage forecasts for air, rail, bus and automobile modes, following the steps of traditional forecasting: trip generation, distribution, modal split, and assignment. These forecasts represent predictions of how many people will travel, where they will travel, why they will travel (e.g., business or pleasure), and what mode or modes they will select.

Demand estimates are traditionally derived from econometric models that quantify travelers' responses to changes in service characteristics: trip time, cost, frequency of service, and accessibility. These models are calibrated using actual ridership data for systems with known service characteristics. Demand estimates for systems involving a new facility or service are obtained by applying the calibrated models to the service characteristics of that new system. Other inputs to the modeling process include estimates of population, employment and other socio-economic conditions that influence travel behavior.

The methodology adopted in Phase 1 of the Pennsylvania HSR study entailed the selection of a set of traditional econometric models, calibration of those models, and their application to the several HSR alternatives. These estimates of demand became the "base" estimate of travelers' responses to the alternatives. The effects of less quantifiable service characteristics were also estimated, resulting in the "high-demand" estimate. The base estimate represents a conservative set of assumptions and the high-demand estimate a more optimistic set of assumptions.

9.1.1 Literature Review

A review of the literature on intercity travel demand modeling was conducted. All of the modeling systems studied fall into one of three categories: pre-distribution methods; post-distribution methods; and hybrid methods. Pre-distribution modeling methods, sometimes referred to as direct demand estimation models, use socio-economic conditions and travel conditions to estimate patronage or travel volumes on one mode. Although they are easy to apply, they do not provide information on the redistribution of travel among competing modes, and are insensitive to major changes in modal characteristics. Post-distribution methods use at least the first three steps in the standard demand estimation process: trip generation; trip distribution; and modal split. These modeling methods are designed to provide more complete information on total travel conditions and are sensitive to changes in the service characteristics; however, they require large quantities of data and are typically more complex, involving considerable data processing and manipulation. Hybrid models provide a compromise between the pre- and post-distribution approaches.

Seven rail studies conducted between 1975 and 1984 were evaluated; all adopted post-distribution modeling methods. The trip generation and distribution steps were accomplished either by applying a single model or two separate models to develop a total person-trip table (volume of trips among all possible origins and destinations). The use of individual modes was then estimated using a modal split or mode choice model. The modal split models are either gravity model formulations, (using the ratio of modal attributes to systemwide attributes to determine the percent utilization of that mode) or other formulations such as the multinomial logit model.

Most of the studies considered the total market to consist of two segments, "business" trips and "non-business" trips. Depending on the study, "business" may or may not include commuter travel. "Non-business" generally includes tourist travel, personal business, social and "other" trips (and commuter, if appropriate). Different coefficients were specified for each market segment during the calibration of the models.

9.1.2 Selected Methodology

The methodology selected for estimating demand in this study follows the post-distribution format and employs a logit modal split model. The study area was first divided into zones. Counties were selected as the appropriate zonal boundaries for this phase of the study. County-to-county person-trip tables were developed for the year 1980 and, in conjunction with transportation service characteristics and information on mode use in 1980, the modal split model was then calibrated.

Projections of demand for the year 2000 were made by first expanding the 1980 trip table. Transportation system characteristics were estimated for each of the alternative high-speed rail systems for the year 2000. The modal split model was then applied to estimate the proportion of trips that would use each available mode.

Adjustments were subsequently applied to account for those attributes of an HSR system that are not accounted for in the rail mode split equation. A method of estimating the effect of a new "image" for HSR service was developed. Methods of estimating "induced" travel (travel that is made simply because there is a new mode) were investigated. The effects of different land use assumptions, different alignments, and different accessibility to services and activities outside Pennsylvania were also estimated. The results of these investigations were used to develop estimates which are more optimistic than the base estimates.

Estimating Total Demand

Data were compiled from existing sources regarding the volumes of travel or each of the four major intercity travel modes: auto, bus, rail, and air. Some of the data, most notably that for auto travel, were for years other than the base year selected for this study (1980). Auto trip data were also in terms of vehicle-trips rather than person-trips. Adjustments were made in the data to estimate the tota person-trips made in 1980.

The following equation was used to adjust trip table data for population and employment changes for years other than those for which data are available:

$$T_{ijf} = \left(\frac{P_{if} + P_{jf}}{P_{ib} + P_{jb}} + \frac{E_{if} + E_{jf}}{E_{ib} + E_{jb}} \right) \times \frac{T_{ijb} \times AOF}{2}$$

where: T_{ijf} = trips from zone i to zone j for the forecast year

P_{if} and P_{jf} = Population of zones i and j in the forecast year
E_{if} and E_{jf} = Employment of zones i and j in the forecast year
P_{ib} and P_{jb} = Population of zones i and j in base year
E_{ib} and E_{jb} = Employment of zones i and j in base year
T_{ijb} = trips from zone i to zone j for the base year
AOF = vehicle occupancy factor if T_{ijb} is in terms of vehicle trips.

Adjustments were also made for changes in trip-making rates over time based on a literature search. The primary source is the final report of the National Transportation Policy Study Commission (NTPSC).[1] Intercity travel forecasts included in the NTPSC study were used to compute the growth trends of intercity trip generating rates at the national level.

The NTPSC study made forecasts based on three scenarios of future conditions: low-growth, medium-growth, and high-growth. For purposes of this study, the medium-growth scenario was selected. Table 9-1 shows salient statistics for the base year (1975) and for the forecast years of 1985 and 2000 for the medium-growth scenario. Table 9-2 shows the forecast intercity person-trips by mode for the medium-growth scenario. Table 9-3 contains the trip generation rates computed from the data presented in the two previous tables.

As can be seen in Table 9-3, the number of intercity trips per person per year is expected to increase 55 percent (from 63 to 98) nationwide during the 25-year period (1975 to 2000). This means that even if the population stays constant for the period, the number of intercity trips will increase by 55 percent. This increase was attributed to the following reasons in the NTPSC Study:

1. Expansion of industries and occupations with high travel potential, such as service industries and white-collar occupations, will increase business travel faster than the general level of economic growth;

2. Increased affluence and more leisure time will stimulate pleasure travel and tourism;

3. Changing age distributions mean more persons in high-travel-potential age groups;

4. The trend toward fewer dependents allows more time and disposable income for travel; and

5. The rising relative affluence of other countries will increase tourism to the United States, creating new demands on the intercity system.[2]

The highest increase in travel by mode (153 percent) is forecast for air and the lowest (38 percent) is forecast for the rail mode based on past trends of travel demand. The NTPSC study recognized the absence of an efficient intercity travel mode for short- distance intercity travel markets as indicated in the following statement:

> "Present intercity service offers limited speed and cost options. In short-range markets, there are no substantial high-speed options--air being relatively slow due to excessive access times, and the auto and bus being

TABLE 9–1

NATIONAL STATISTICS FOR MEDIUM-GROWTH SCENARIO

	1975	1985	2000	2000/ 1975
GNP (billions of 1975$)	1529	2276	3588	2.35
Population (millions)	214	233	260	1.21
Households (millions)	71	90	104	1.46
Civilian Labor Force (millions)	95	109	124	1.31
Disposable Personal Income per Capita (1975 $)	5078	6853	9826	1.94
Person-Miles (trillions)	2.6	3.3	4.6	1.77
Ton-Miles (trillions)	2.4	3.5	6.3	2.63
Energy Consumed by Transportation (quads)	17.4	17.7	22.3	1.28
Highway Fatalities (thousands)	46.0	53.4	66.9	1.45
Metric Tons of Air Pollutants in Urban Areas (millions)	50.8	38.8	38.6	.76

Source: Reference 1

TABLE 9–2

FORECAST INTERCITY PERSON-TRIPS* FOR MEDIUM-GROWTH SCENARIO BY MODE OF TRAVEL (millions)

Mode	1975	1985	2000	2000/ 1975
Air	282	430	866	3.071
Auto	12,976	16,513	24,170	1.813
Bus	239	268	412	1.724
Rail	31	37	52	1.277
TOTAL	13,528	17,249	25,499	1.885

Source: Reference 1

* Intercity trips were defined as those greater than 30 miles and with a destination outside the urban or rural locality of origin.

TABLE 9–3

INTERCITY TRIP GENERATION RATES BY MODE (Annual Person-Trips/Person)

Mode	1975	1985	2000	2000/ 1975
Air	1.318	1.845	3.331	2.527
Auto	60.634	70.870	92.960	1.533
Bus	1.117	1.150	1.585	1.419
Rail	0.145	0.159	0.200	1.379
TOTAL	63.214	74.024	98.076	1.551

> fixed at a maximum upper speed limit of 55 miles per hour. This market is often indicated as having potential for high-speed rail service; however, substantial capital investment is required. Where auto, bus, and air speeds are often impaired by road and airway congestion, rail services may gain market share when rail speeds and service levels begin to compare favorably with the other modes."[3]

However, the NTPSC forecasts of intercity travel by rail did not consider further market penetration by HSR. Although there will be readjustments within the modes when HSR service is implemented, the intercity trip generation rate obtained for all modes was assumed to be unaffected for purposes of this study.

In order to establish that the national estimates prepared by NTPSC are applicable to the study area, the growth trend of passenger auto volumes on the Pennsylvania Turnpike was compared to national statistics. The Turnpike is the major facility for intercity auto travel in the study area. Since the vast majority of intercity trips is made by automobile (96 percent in 1975 at the national level), it is reasonable to assume that automobile traffic growth on the Turnpike reflects the growth trend of overall intercity trips in the study area. Although Turnpike traffic includes trips of various lengths, trips made from outside the study area into the study area and vice versa, and trips passing through the study area, the majority of the auto trips on the Turnpike have been found to be intercity trips (more than 30 miles) within the study area corridor.

During the period 1963 to 1980, the number of automobile passenger-miles on the Turnpike increased by about 75 percent, while the number of national auto passenger-miles increased by 84 percent; these trends are shown in Figure 9-1. Note that the statistics derived from the Pennsylvania Turnpike closely parallel national trends throughout the 17-year period. This close comparison provides confidence in the application of national trip generation rates to Pennsylvania.

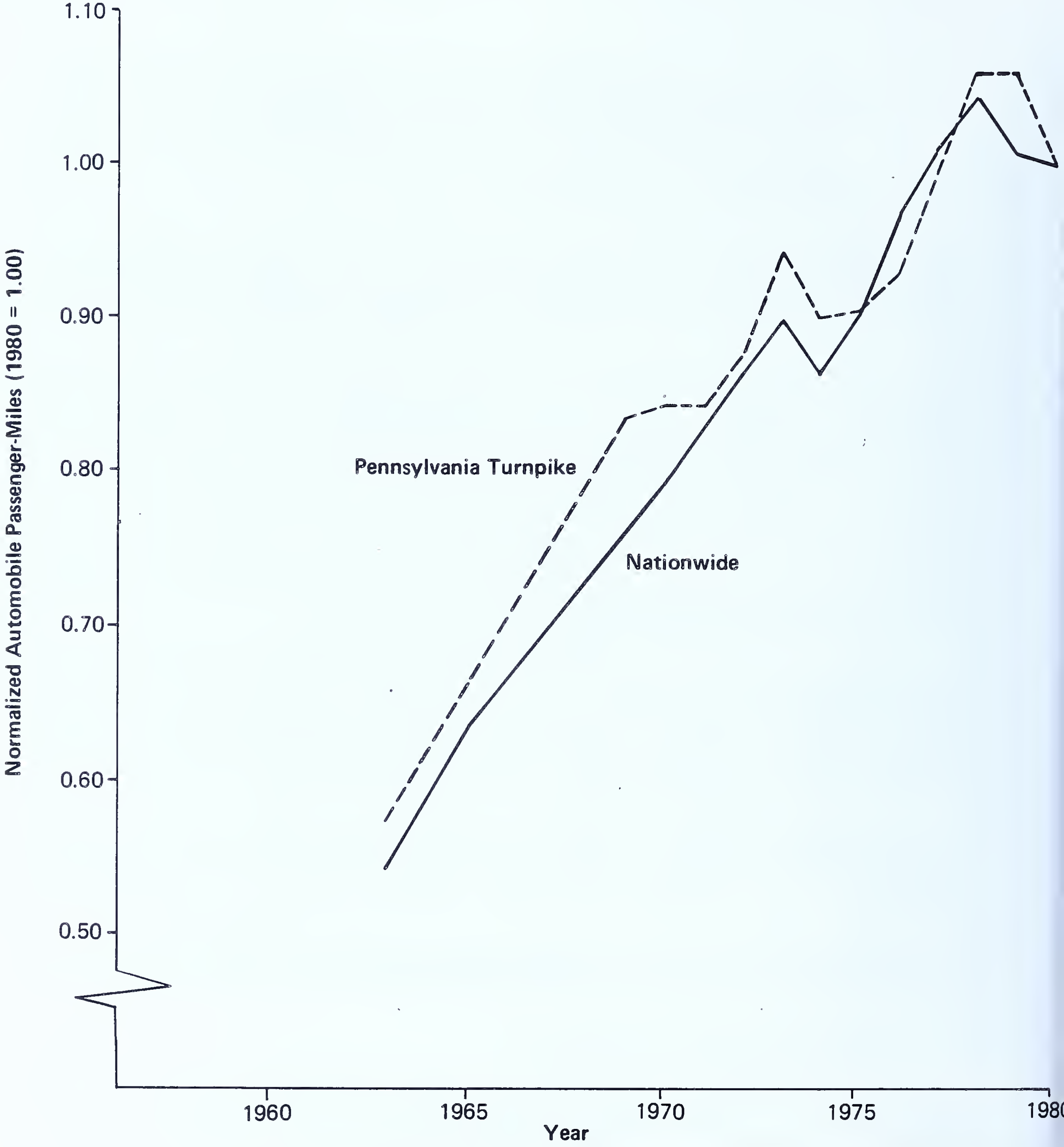
As there are significant numbers of intercounty trips which have trip lengths of less than 30 miles (and thus do not fall within the definition of intercity trips in the NTPSC Study but are potential HSR trips), a separate analysis was undertaken for these trips.

The increases in the trip generation rates were used to obtain 1980 and 2000 county-to-county trip tables which are later employed in the modal split analysis.

Market Segmentation Approach

This study identifed four market segments as significantly different in their modal split characteristics: commuter trips, business trips, tourist trips and "other" trips. There is evidence to suggest that there are significant differences in traveler behavior between business and commuter trips, between tourist and business trips and between tourist and commuter trips.

- o A business trip is a non-daily trip made to conduct some sort of business activity. Business trip costs are generally paid by an employer who has a tendency to view the full costs of all modes in comparison to the time cost of an employee's travel time.



Source: Motor Vehicle Manufacturers Association, Pennsylvania Turnpike Commission.

Figure 9-1
Automobile Passenger-Miles

- Commuter travel is short-distance daily travel paid by the employee. The commuter is more apt to perceive costs by all modes as the out-of-pocket cost and to compare cost to wages rather than the total value of time from an employer's viewpoint. Thus, commuter travel is probably more sensitive to cost (in comparison with the highway mode), while business travel is more sensitive to travel time.

- Tourist trips have characteristics that differ from the other segments. Costs are generally much more important than travel time. For certain types of activity centers such as parks and camping areas, no mode can compete with the automobile/camper.

- "Other" trips include: trips for personal business or family affairs; social, recreational or other pleasure trips; and shopping trips. That is, all other trips not included in the previous three market segments.

Based on these considerations, the total person-trip table was partitioned into four segments before applying the modal split model. Data on trips by trip purpose were used to define the volume of trips between specific origins and destinations. The modal split model was also partitioned and applied to each market segment separately. Further discussion of trip table partitioning is contained under model calibration.

Estimating Modal Split

The modal split model is based on the economic theory of consumer behavior embodied in a logit statistical model developed by Alan Grayson.[4] Mode choice is related to the interrelationships among the travel cost, travel time, frequency of service, and access distance of all four travel modes: rail, bus, auto and air. The general form of the logit model and the utility equations for each mode are illustrated in Figure 9-2. The mode choice model is calibrated with data from the National Travel Survey of 1977,[5] supplemented by common carrier service information for selected routes. The modal split model was re-calibrated for use in this study as explained under model calibration.

Additional Demand Considerations

The traditional modeling process has been shown to be a valuable tool for estimating travel demands for systems that are similar to existing facilities and services. There are, however, effects of significantly different transportation systems that are not adequately predicted by simply changing travel time, travel cost, service frequency, and accessibility variables. These effects include: traveler perceptions of the safety, comfort, convenience, and amenities associated with a new, high-quality service; the effects of induced development within the corridor; and improved accessibility to activity centers outside the immediate study area. There is also an effect referred to as "induced travel" that has been included as a component of total travel demand for new systems in some studies. These considerations are described below.

Estimating the Effect of HSR Image

The mode choice model selected for this study uses the service characteristics of the alternative modes (cost, travel time, access and frequency of service) and an

$$P_c = \frac{e^{U_c}}{\Sigma\, e^{U_i}}$$

where: P_c = Probability of choosing mode c

e = Base of natural logarithms

U_i = Utility or relative value of mode i

$$U_i = aC_i + bYT_i + \frac{cY}{2F_i} + dYA_i + F_i$$

where: C_i = Cost of mode i, in dollars

T_i = Travel time of mode i, in hours

F_i = Frequency of mode i (average departures per hour)

A_i = Access of mode i (miles to common carrier terminal)

$$Y = \frac{\text{Annual family income in dollars}}{\text{2,000 working hours per year}}$$

Constant	Type of Trip			
	Commuter	Business	Tourist	Other
a	-.0328	-.0328	-.0111	-.0111
b	-.0200	-.0200	-.0079	-.0238
c	-.0244	-.0244	-.0030	-.0090
d	-.0006	-.0006	-.0015	-.0016
f air	-1.313	-1.313	-3.435	-3.166
f auto	0	0	0	0
f bus	-3.159	-3.159	-1.797	-3.016
f rail	-2.461	-2.461	-3.288	-2.828

Figure 9-2

Modal Split Model Equations[4]

indicator of the users' ability to pay for services (family income) to estimate the utilities of the available modes. The model includes a constant term for each mode that in theory includes all the remaining characteristics of a mode, real or perceived, that influence modal choice. The constant term represents characteristics such as the quality and comfort of the ride, the perceived safety of the trip, amenities provided to or available to the passenger, and other qualities of travel by a given mode that are difficult to model. The constant term in the mode split equation which embodies these factors is known as the mode bias coefficient or "image factor". The value of the mode bias coefficient in models of the logit type is established during model calibration by finding the best fit of the equation to observed data.

Models of this type are intended to estimate the ridership impacts of changes in the service characteristics of an existing mode or modes. However, if a new mode is introduced or if an existing mode is improved to such an extent that its level of service is dramatically enhanced, these models in their original formulations are unable to determine the impact of the new mode on mode choice.

It would be most desirable to develop an image factor for HSR based on observed travel behavior for similar service operating within the study region. The next best solution would be to develop an image factor based on observations of similar services operating in other regions. Since there are no HSR systems operating in the United States, neither of these two approaches could be adopted for this study.

The philosophy adopted is to assume that the new HSR service will be operated and perceived to be more like air travel than conventional rail travel. In the range of trip lengths that are being considered in this study, the travel times and other service characteristics of HSR are comparable to the air mode. The new HSR service concept (Chapter 6) anticipates a new entity operating HSR service, rather than Amtrak, and its mission would be to provide a premium-quality service on the totally-rehabilitated or new physical plant embodied by Alternatives C, D or E. The effect of this assumption has been tested by substituting the air mode bias coefficient for the rail coefficient in computing modal split. The demand estimates which result from this adjustment to the mode bias coefficient are referred to as "high-demand" estimates rather than "base" estimates; they represent more optimistic assumptions than the base case.

Estimating the Effect of a Mid-State Resort Development

The presence of a major tourist-travel generator in the mid-state area would increase HSR ridership, possibly substantially. The mid-state location was selected for study because such a location would cause the largest increase in passenger-miles, i.e., the longest average trip length.

A review of the characteristics of 12 major resort complexes was conducted to determine the general requirements for a similar development in the mid-Pennsylvania area and the possible size of the total market. These characteristics included: the physical size of each facility; the lodging and convention facilities; recreational characteristics, such as number of ski slopes, golf courses, tennis courts, swimming and fishing facilities; and historic or amusement center attractions. The resort complexes reviewed were: Seven Springs (Pa.), Hidden Valley (Pa.), Blue Knob Ski Area (Pa.), Gettysburg National Military Park (Pa.), Hersheypark (Pa.), Snowshoe Ski Area (W.Va.), Killington Ski Area (Vt.), Summit Lodge (Vt.), Americana Great Gorge Resort (N.H.), Indian Lake Resort (Ill.), Eagle Ridge Inn & Resort (Ill.), and Steamboat Springs (Colo.). Based on this review, the following range of total market potentials was estimated:

Characteristics	Possible Annual Market
Complete summer/winter resort complex with recreation, lodging, and convention facilities	3 million visitors
All characteristics of preceding development plus a major theme park, museums and historic attractions	7 million visitors
All characteristics of preceding development plus major entertainment and casino facilites or some other major novel attraction.	10 million visitors

The next aspect of estimating possible HSR use related to such a facility is to determine how the market is distributed among possible origins. Data were obtained from a recent survey conducted by the Harrisburg/Hershey Area Tourist Promotion Agency on the residence of visitors to Hersheypark. These data were used to specify a simple linear model providing the percentage of visitors as a function of population and distance. This equation was used to estimate the origins for the hypothetical mid-state resort development. The mode share for HSR was then determined and ridership estimates were produced.

Estimating the Impacts of Philadelphia-Atlantic City Rail Service

In 1982, there were approximately 16.3 million trips to the Atlantic City resort/entertainment complex (15 million by automobile, 1 million by bus, and .3 million by air). The New Jersey Department of Transportation estimates a growth rate in these trips of between 2 percent/year and 4 percent/year. Applying these growth rates results in a low estimate of 23.3 million trips per year and a high estimate of 33.0 million trips per year by the year 2000.

The distribution of origins for present trips to Atlantic City was available from a survey conducted by the New Jersey Department of Transportation. A simple linear regression model similar to that developed to predict the distribution of origins for a mid-state resort development was employed using this data. Modal split estimates were provided by the modal split model for origins in Pennsylvania assuming an interconnection at Philadelphia between the proposed Atlantic City rail service and HSR.

Induced Travel

Induced trips are those that did not exist on any mode prior to implementing the new service or facility. Induced trips are therefore not diverted from other modes.

These trips result from a change in trip generation because of the improved accessibility between locations served by the new system; or a change in trip distribution due to the change in the desirability of traveling between the locations served with respect to other potential origins and destinations, or because of the increased level of activity in the vicinity served by the new service or facility. In theory, all three components of induced travel could be estimated if the prediction of future land use, the trip generation models, and the trip distribution models were sensitive to such changes in the transportation system. For this reason, many forecasters are opposed to estimating induced travel outside of the traditional modeling system. In some cases, however, estimates of HSR demand from traditional model systems have under-estimated actual ridership.

In practice, the trip generation models are seldom sensitive to transportation system changes. Land use projections are frequently modified based on the effect of implementing a new transportation facility or service. However, these changes are seldom fed back into the trip generation models. Therefore, travel demand impacts are lost. It is not uncommon for trip distribution models to be sensitive to changes in the transportation system, although the redistribution of trips resulting from such changes is usually very small.

Little information is provided regarding the methods for estimating induced travel in the published reports of other studies, and that provided appears to rely heavily on judgment. In one study (Los Angeles-San Diego), 1 percent per year compounded annually for 18 years is used; however, little evidence is provided to support this approach. Induced travel is considered in the Los Angeles-Las Vegas study and in the Florida study, although the methods of estimating it are not clear. Induced travel is not estimated in the Toronto-London-Windsor study.

The methodology selected to produce the base estimates of travel demand in this study does not provide for transportation sensitivity in the trip generation or distribution steps. Trip generation and distribution for future years were accomplished by making adjustments to trip tables for existing trips, based on changes in trip-making rates, population, and employment. Although the induced development estimated to occur as a result of HSR could be used to modify this adjustment process, the total economic impact is such a small portion of the base (less than 1 percent) that any changes in trip-making activity predicted using this technique would be insignificant.

The modal split model selected for use in this study is based on utility theory. That is, modal split is a function of the travel utility provided by each mode. Utility is measured as a function of travel time, cost, frequency of service and accessibility. When a new mode of travel is introduced, or when significant changes occur in an existing mode, the utility of that mode increases. When the utility of a mode increases, the composite utility of travel by all modes increases. It is reasonable to assume that the change in composite utility is related to induced travel.

Using this concept as a starting point, a model was developed to estimate induced travel. Because of the lack of any direct calibration or validation evidence, however, the resulting estimates of induced travel are not employed in later steps of this study.

9.2 MODEL CALIBRATION

Model calibration is the process of specifying the parameters in the models so that they duplicate travel conditions for the year in which calibration data (i.e., both independent and dependent variables) are available. Calibration provides confidence that the predictions of future travel are reasonable.

The modeling process adopted for this study has three major elements: trip table building, modal split, and trip assignment. The first element involves the use of available information to determine the number of trips generated in each zone (county) that are destined for every other zone (county). The second element uses a modal split model to determine the portion of trips between specified origins and destinations that will use each available transportation mode. Finally, the trip assignment element is used to separately forecast the path that each trip will take through the network between each origin and destination, and the volume of traffic on each link in the network. The interrelationships among these three basic elements are presented graphically in Figure 9-3 along with other essential elements of the modeling process.

In order to complete model calibration, the existing transportation system serving the Philadelphia-Pittsburgh Corridor was simulated using the Urban Transportation Planning System (UTPS). The validity of the adopted modeling process was examined by answering the following three key questions:

1. Is the output of each model element reasonable?
2. Are individual models properly and efficiently interconnected?
3. Do trip assignment results simulate (duplicate) existing conditions accurately?

A systematic calibration process, using computer output summary tables for each modeling element, was used to answer these questions. This section of the report documents the existing transportation system base year conditions and summarizes the calibration and sensitivity testing results.

9.2.1 Abstracting the Transportation System

The purpose of applying any travel demand modeling technique to the analysis of transportation system alternatives is to predict the response of travelers to the changes in travel conditions represented by alternative transportation facilities and services. To accomplish this objective, the models must contain variables that describe the service characteristics of each alternative transportation system and relationships that describe the response of travelers to changes in the service characteristics. Some method of estimating or calculating these variables is required first to identify the relationships and then to determine traveler responses to changes in these variables. This is typically accomplished by abstracting the study area and its transportation system for computerized network representation and analysis. The impact of proposed alternatives can then be estimated by changing appropriate transportation network elements and subjecting the revised network to computerized analysis.

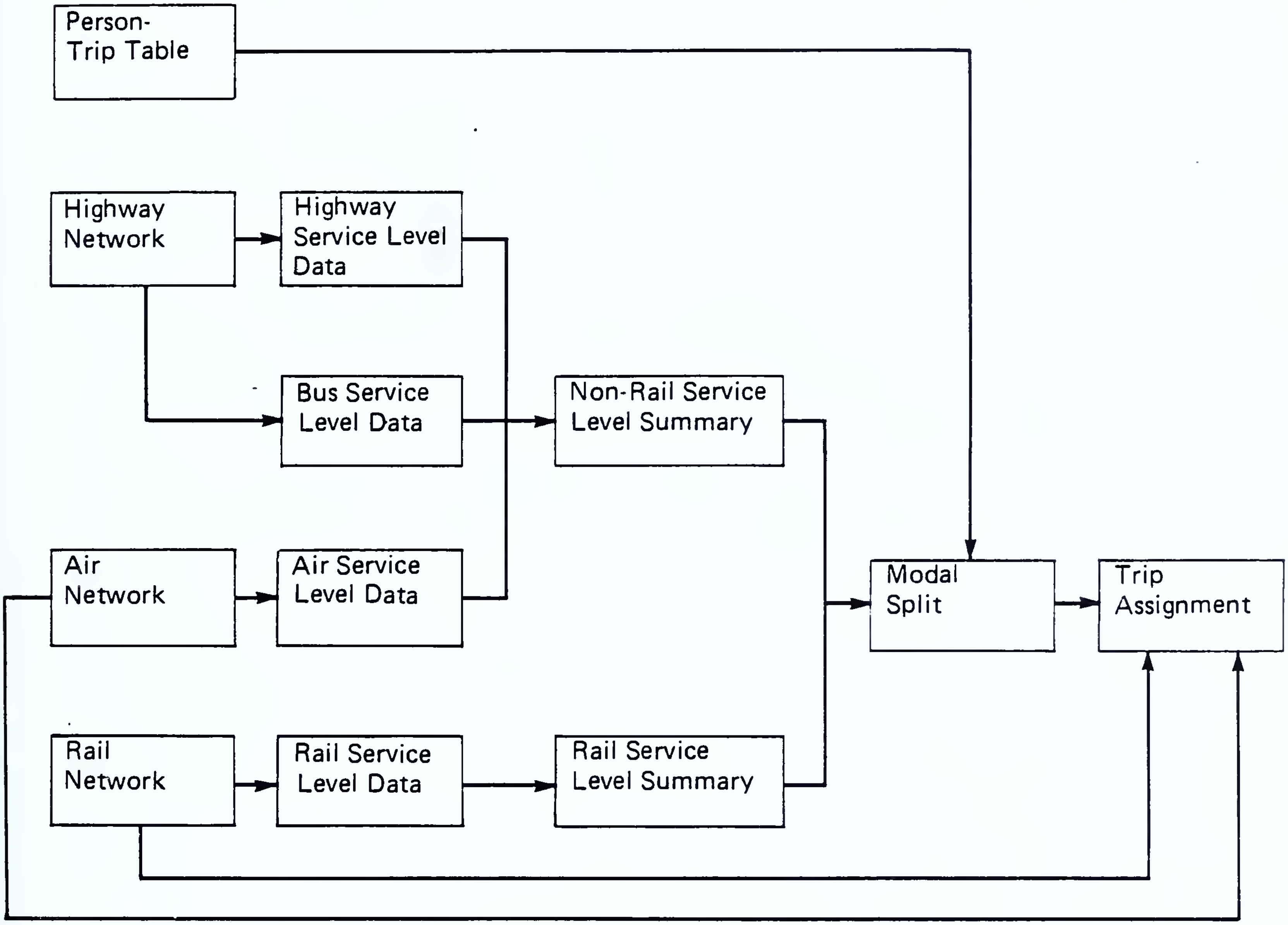


Figure 9-3
Demand Estimating Methodology

The abstraction of the study area was accomplished by dividing it into a series of zones. Travel is then described by the number of trips from each zone to all other zones. All travel activity in a zone was assumed to be concentrated at the population center of that zone. That is, all trips to or from any zone are assumed to originate or terminate at the population center.

The transportation network is represented by a series of nodes and links. Nodes are locations where network elements (links) change characteristics or where network elements intersect. The nodes are numbered to facilitate computer processing and analyses. Links are defined by the nodes at the ends of the links and by the distance, cost, frequency of service, travel speed, capacity or other relevant characteristics of the network element between these nodes. The networks are connected to the zonal centroids that represent the study area by centroid connector links that represent the "average" or "normal" travel times, travel speeds, costs, etc., required to gain access to the network.

The following sections describe the procedures used to abstract the study area and the existing transportation network to calibrate the models adopted for the study. Separate descriptions are provided for each element of the abstracted system.

Study Area

Originally, 29 counties were selected to represent the primary impact area of the proposed HSR alternatives. Fourteen more counties were added, representing a secondary impact (feeder) area, to make a total of 43 counties. These 43 counties cover the lower two-thirds of Pennsylvania and include a majority of the state's population, employment and activity centers.

After a review of data and projections available for the study area, it was decided to use the county as the primary area analysis unit. Data and projections describing the socioeconomic conditions within the study area are available at the county level, while breakdowns by minor civil division or by municipality are not complete. The number of zones that would result from using minor civil divisions far exceeds the number that can be reasonably and efficiently handled in this study. In addition, the level of detail that would be required to develop a network serving that large a number of zones is far beyond what is justified from the standpoint of the accuracy and reliability of the travel demand estimating procedures and results for Phase 1 of this study.

The county center locations were approximated by examining the population and employment distributions within each county. The counties within the study area are shown in Table 9-4, together with population, employment, and average family income data for the years 1980 and 2000.

Highway System

The highway network for the study consists of all major east-west roads and highways in the 43-county area that represent competitive alternatives to any HSR service plus all major north-south routes that act as feeders to east-west facilities. After these facilities were identified, they were abstracted for computer representation as a series of nodes and links. Characteristics of each link such as its distance, travel speed, and classification were identified to complete the abstraction. The network was then connected to the zonal centroids representing the study area counties.

TABLE 9-4

STUDY AREA SOCIOECONOMIC DATA[11]
Years 1980 and 2000
(thousands)

County	Population		Employment		Family Income (1980 Dollars)	
	1980	2000	1980	2000	1980	2000
Beaver	205	208	83	88	22	39
Allegheny	1,448	1,391	735	785	22	38
Washington	217	227	76	79	21	32
Greene	40	45	14	14	18	29
Indiana	93	106	35	44	19	34
Westmoreland	393	422	139	158	20	32
Fayette	160	169	42	42	17	26
Cambria	183	187	69	71	19	30
Somerset	81	88	28	31	17	28
Blair	137	142	58	61	18	29
Bedford	47	52	15	15	15	23
Huntingdon	43	47	14	16	16	25
Fulton	13	15	4	5	15	26
Mifflin	47	52	18	18	17	26
Juniata	19	23	7	8	16	22
Perry	36	45	8	8	18	23
Cumberland	179	210	94	132	22	41
Franklin	114	130	51	58	19	31
Adams	69	86	27	32	19	27
Dauphin	233	263	146	175	21	37
York	314	376	153	177	21	33
Lebanon	110	126	46	53	20	32
Lancaster	364	430	178	219	21	33
Berks	313	349	156	168	21	33
Chester	319	370	139	174	26	40
Montgomery	645	705	373	450	26	45
Delaware	555	552	202	220	23	35
Philadelphia	1,685	1,620	851	787	16	28
Bucks	481	571	187	255	24	37
Lehigh	274	307	145	172	22	37
Northampton	226	247	98	97	21	31
Columbia	62	75	27	32	16	26
Montour	17	17	10	17	19	51
Northumberland	100	108	38	34	16	23
Schuylkill	161	172	56	52	16	24
Union	33	38	15	21	18	34
Snyder	34	38	14	16	17	27
Centre	113	132	49	58	19	31
Clearfield	84	96	31	40	17	30
Clarion	44	51	15	18	19	31
Armstrong	78	82	24	25	18	27
Butler	148	173	53	50	21	32
Lawrence	107	115	36	38	19	30
TOTAL	10,024	10,660	4,559	5,023	-	-

Highway network nodes were located at all intersections and interchanges between network routes. Nodes were also added at Turnpike interchanges to permit the modeling of tolls. Distances were scaled for each of the resulting links. Each link was categorized using the following classification scheme:

- o Class 1 - Limited access routes having an average travel speed of 55 mph
- o Class 2 - Other major routes having an average travel speed of 45 mph
- o Class 3 - Minor through routes having an average travel speed of 35 mph
- o Class 4 - Connector routes having an average travel speed of 20 mph

Class 4 connector routes were used to connect the zonal centers or county centers to the rest of the highway network and were assigned a distance of 5 miles or more representing the average travel required to get from locations within the county to the abstracted highway network. A terminal time of 10 minutes was assigned to highway trips representing the average time required to travel between a parking lot and the ultimate destination plus the time to park the auto.

To test the highway network abstraction of the actual highway system, isochronal maps were developed for highway distance, time and tolls. A number of highway paths were also traced through the network file to see if they were logical. It was concluded that the highway distance, time and toll matrices produced by the simulation process were reasonable for the purposes of this study.

Bus Network

Since the bus lines operate on the highway system, the bus network information was analyzed as a function of highway characteristics. Comparisons between auto and bus travel times based on published schedules provided by Greyhound and Trailways indicated that the bus averaged 44 percent greater travel time than the automobile. Although there are some exceptions, this relationship was judged to be adequate for describing bus travel times throughout the study area. The total travel time for the bus system was calculated as highway travel time multiplied by 1.44 plus access and egress time developed manually.

Air Network

Scheduled air service within the study area was identified[6] and service characteristics then established. Air time, defined as airport-to-airport (arrival minus departure) time, was computed and coded. Distance, defined as airport-to-airport airline distance was scaled from a map.

In the 43-county study area, there are 13 airports with scheduled service. Thus, not every county is directly served by air transportation. However, it was assumed that, either directly or indirectly, every county in the study area has access to air service. The fact that access is provided does not mean that the service will be used, only that travelers have the option available. Utilization was estimated in the modal split step. It was assumed that all access would be by auto and the access distance would be the straight line distance from the center to the airport multiplied by 1.5 to represent actual access distance. A minimum distance of 10 miles was assumed and the average access speed was assumed to be 30 mph. Total air terminal time was assumed to be 60 minutes which includes both origin and destination terminal time.

Rail System

The existing rail network was established in the same manner as the air network. The Amtrak National Timetable was the primary source of information for rail travel times and distances between stations. These values were coded in the UTPS programs.

Level of Service Data

The level of service data required for each mode for the modal split model calibration was obtained largely from the results of abstracting the transportation systems and utilizing the various UTPS programs to process the data. This section summarizes how the independent variables of the modal split model including cost, time, frequency and access and egress distance, were developed.

- Cost

  Most travel demand models, including the ones for the Pennsylvania High-Speed Rail Study, use the cost of travel by different modes as an independent variable in the modal split equations. It is difficult, if not impossible, to accurately represent all possible variations in the costs of travel as they apply to specific origins and destinations, time of travel during the day, and frequency of trip making of the user. Therefore, approximations were used in the modeling process to represent conditions that existed in the base year.

  Data were collected regarding fares for rail, bus, and air travel in Pennsylvania in the fall of 1983. These data were subjected to regression analysis, and coefficients of simple linear equations were estimated. The results were judged to be reasonable for rail and bus services, but too much variation was unexplained by the equation for air travel. Therefore, a matrix providing the actual average full regular fare for air by each origin-destination pair within the study area was developed.

  The equation used to approximate bus fare is:

  $$\text{Fare} = 3.40 + 0.078 \times (\text{Distance in Miles})$$

  The equation used to approximate rail fare was:

  $$\text{Fare} = 0.87 + 0.110 \times (\text{Distance in Miles})$$

  The equations for rail fares and bus fares were used along with the airline fare matrix for calibration of the travel demand models for 1980. The cost of automobile travel was assumed to be 10 cents per vehicle-mile plus parking. The value was divided by the assumed average auto occupancy by trip purpose to obtain a cost per person-trip.

- Time

  For the air and rail system, access and egress time, transfer time, terminal time and line-haul time were added to obtain the total travel time. Total travel time for each origin-destination pair was calculated by abstracting the network as discussed in the previous section. Highway travel time includes in-vehicle time and terminal time. Bus travel time was calculated as 1.44 times highway in-vehicle time plus access and egress time and terminal time.

- Frequency

  The frequency for the highway network was assumed to be infinite. This concept is not completely correct because not all drivers have instantaneous use of a vehicle, but the assumption of infinite auto frequency is acceptable for comparison with other travel modes.

  The frequency used to describe air, rail, and bus services was the "available" frequency. This is not necessarily the frequency for the minimum time path. For example, if express and non-express services exist between two rail stations, both express and non-express frequencies should be included, although the express service is likely to represent the minimum time path.

  The time period used for the common carriers for defining the service frequencies was from 6:00 am to 10:00 pm, a total of 16 hours. Thus, the number of services per hour equals the total number of services during the specified time period divided by 16 hours.

- Access and Egress Distance

  The access and egress distance for users of the highway network is assumed to be zero. This assumption is based on the fact that all travel paths begin and end at the county centroids. However, travel distance to or from parking lots is considered in the total travel time calculation as terminal time.

  The access and egress distance for the rail, air and bus system was obtained based on the following assumptions:

  - Auto is the only access mode
  - Access and egress distance is the straight-line distance from the centroid to the staion or airport multiplied by 1.5 to represent actual distance
  - Access and egress distance is a minimum of 5 miles for rail and bus and 10 miles for air

9.2.2 Establishing Base Year Conditions

The development of a 1980 person-trip table for the model calibration reflects the requirements of the selected methodology described in Section 9.1.2. The methodology provides for four market segments: commuters, business travelers, tourists, and other trips. The 1980 trip table consists of four 43-by-43 element matrices (one for each trip purpose) representing trip interchanges among all 43 zones within the study area. These zones represent individual counties in accordance with the selected format for compiling socioeconomic data for this study.

The trip table development process began by assembling the number of person trips by each mode for the year 1980. These figures were then summed to create a total 1980 person-trip table. The number of total trips was then divided into the four market segments for use in the model split model.

Trip Table Data Sources

The creation of the 1980 person-trip table involved the summation of travel by all modes including, air, rail, bus and auto trips. The largest segment of this trip table consists of auto trips, data for which were derived from a 1963 county-by-county survey.[7] Since the data represents 1963 information, adjustments were necessary to provide auto trips in 1980. The adjustments were based on changes in population and employment for each county between the years 1963 and 1980, and for differences in the tripmaking rates of individuals, over that time period. Information for the 1980 rail and air trips was provided by Amtrak and the Air Transport Association, respectively.

The data for partitioning total trips by purpose were obtained from two sources. Statistics for the commuter and business trips were extracted from the 1980 census document "Place-of-Work Data". Data used to create the tourist trip table were available from the Pennsylvania Department of Commerce. The "other" trips market segment was computed by subtracting commuter, business, and tourist trips from total trips.

Adjustment to 1980 Base Conditions

Factoring the 1963 vehicle-trip data from the Edwards and Kelcey Study into 1980 auto person-trips was accomplished by using the procedure described in the section on Methodology.

Because the Edwards and Kelcey study provides the 1963 trip table in a vehicle-trips format, an auto occupancy factor has to be applied to obtain the number of person-trips for the year 1963. The factor used was 1.1 persons per vehicle. Study area totals for population and employment for the years 1963 and 1980 are displayed in Table 9-5. Also shown are the number of vehicle-trips and the percent change in each category. The 3 percent change in total vehicle trips shown in Table 9-5 represents growth due only to changes in population and employment. Changes in trip-making rates per person from 1963 to 1980 were also examined. Using NTPSC data, calculations were performed to provide new trip generation rates for two trip categories. For trips greater than 30 miles, a 55 percent increase was calculated, while trips less than 30 miles experienced only 10 percent growth. Applying these factors resulted in an overall increase of 38 percent to the trip table.

The number of air trips for the year 1981 was obtained from the Air Transport Association (ATA) by origin and destination airport for the major urban areas including Pittsburgh, Harrisburg and Philadelphia. Trips on commuter airlines not included in the ATA survey were estimated using the number of daily flights

TABLE 9-5

STUDY AREA SOCIOECONOMIC DATA AND VEHICLE-TRIPS

Year	Population		Employment		Daily Vehicle-Trips	
	Study Area Total (Thousands)	Percent Change	Study Area Total (Thousands)	Percent Change	Study Area Total (Thousands)	Percent Change
1963	9,827	-	3,688	-	1,964	-
1980	10,024	2.0	4,559	23.6	2,023	3.0

TABLE 9-6

1980 DAILY PERSON-TRIPS BY PURPOSE

	Study Area		Major Urban Areas[12]
	Daily Person-Trips	Percent By Purpose	Percent By Purpose
Commuter	1,156,530	34.3	30.0
Business	305,610	9.0	12.0
Tourist	116,920	3.5	58.0
Other	1,795,950	53.2	
TOTAL	3,375,010	100.0	100.0

and the seating capacity of the aircraft. Since the trips were recorded from airport to airport, a distribution of these trips to the counties surrounding the airports was made based on the relative populations of the surrounding counties. More direct origin/destination data for commuter air service will be incorporated during Phase 2.

In a similar manner, the number of rail trips for June 1983 was extracted from information provided by Amtrak. This data was also reported as station-to-station trips, requiring a distribution of these trips to the counties served by each rail station. The same procedure was applied to the rail trips to estimate trips to the surrounding counties. While both the air and rail trips were obtained from data for other than the year 1980, changes between 1980 and the actual date are negligible when compared to the total trip table.

Because information on 1980 bus patronage was not available from the bus operators, a process was developed to estimate the total number of daily bus trips. The total number of bus passenger trips was calculated by multiplying the number of bus runs between major terminals by 43 passengers per bus run, the average number of seats on intercity buses. The number of bus runs between terminals was obtained from published schedules for Greyhound Lines and Trailways Inc. and its affiliates. This process resulted in an estimated 5,200 daily bus person-trips. Although this is based on an assumption of the number of passengers per bus run, it represents only 0.17 percent of the total trip volume and therefore has little impact on the accuracy of the total person-trip table.

Reliable information about the distribution of trips by purpose is limited. Data for the commuter and business trips are combined within the 1980 census "Place-of-Work Data". Because the method for reporting information requires the actual place of work during the "reference" week of the census, business trips were included. In order to separate the two purposes, an assumption was made about trip purpose based on length. Trips of less than 60 miles were considered to be 85 percent commuter and 15 percent business. For trips greater than 60 miles, only 5 percent were considered commuter while the other 95 percent were designated business trips.

The tourist trip table was estimated based on tourist data by which a relationship was established between the number of tourists and the amount of tourist expenditures. Data were available detailing travel expenditures for each county, and certain counties had estimates for the annual number of tourists. A factor was generated by dividing tourist expenditures by the number of tourists for those counties for which tourist data were unavailable. For counties with populations of between 312,000 and 643,000 residents, the average value was determined to be $60/tourist. A value of $35/tourist was computed for the other counties with less than 312,000 residents. These factors were used for all counties that lacked estimates of tourist travel.

With the number of tourists destined for each county estimated, a method was needed to distribute the trip origins among all other counties. This distribution process was based on the following assumptions:

- o Only 35 percent of the tourist trips have origins within the study area.
- o The trips to each destination county are based on the origin county's population.

- The origin county's population divided by total study area population determined the percentage of trips to each destination county.

The results of this distribution provided a zone-to-zone tourist trip table.

The volume of the remaining or "other" trip purpose was calculated by subtracting the number of commuter, business and tourist trips from the total number of person-trips for all modes previously calculated. Table 9-6 shows the total trips by purpose for 1980 and lists the percentages from previous studies for comparison. By examining previous studies, it can be said that the assumptions made for the trip purpose calculations yielded reasonable results.

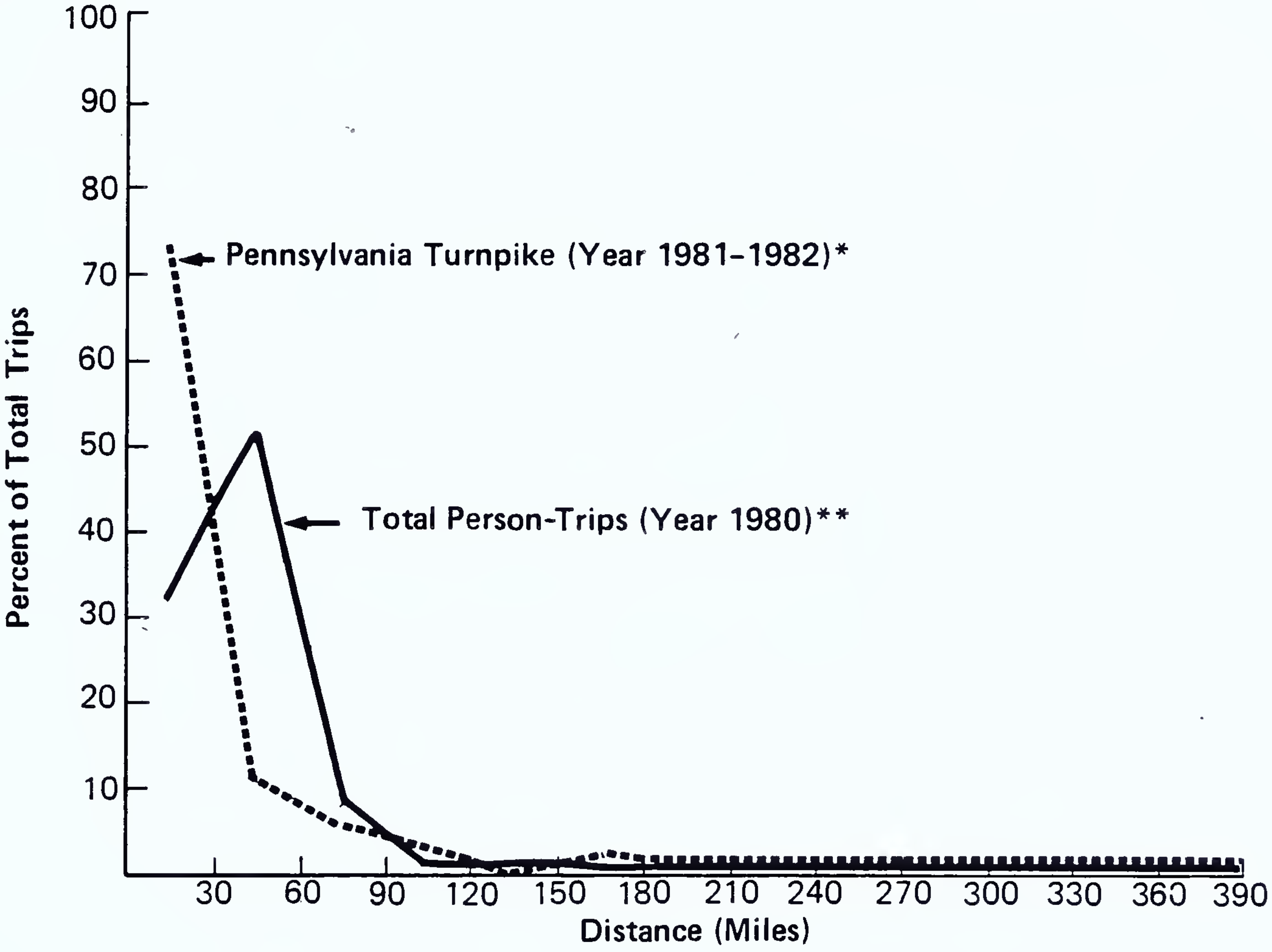
Further comparisons were performed to check the reasonableness of the 1980 trip table. Figure 9-4 displays a comparison of the Pennsylvania Turnpikes trip length distribution with that of the 1980 total person-trips. For trips of more than 120 miles, the 1980 trip table compares well with the Turnpike data. For the 45-to-75 mile range, a noticeable difference occurs between the Turnpike data and the 1980 trip table. This is because the Turnpike data is recorded as interchange-to-interchange distance, while the 1980 trip table paths are recorded as the total distance between zones. By adding an access distance to each end of a trip on the Turnpike, the resultant comparison is quite reasonable. The sharp drop in number of trips of less than 45 miles in the 1980 trip table resulted from the exclusion of intracounty trips. These short trips are excluded from the analysis because the travelers they represent are not potential HSR users.

To develop the year 1980 total person-trip table for model calibration, the 1963 auto trip table was factored up to develop the "other"-purpose trip table. Commuter-, business- and tourist-trip tables were developed directly from the most recent (1980) census and information from the Pennsylvania Department of Commerce.

The procedures adopted to build base-year trip tables in Phase 1 will be further verified by conducting a Pennsylvania Turnpike user survey in Phase 2. Key assumptions used for the highway mode in the modeling process will be checked against survey results and revised if required. If the results of the Phase 2 surveys do not provide sufficient confidence in the resulting ridership projections, it may be necessary to conduct more extensive surveys during the Phase 3 financing effort.

9.3 CALIBRATION RESULTS

The purpose of model calibration is to ensure that the combination of travel models and analysis procedures selected for the project form an accurate forecasting tool. Validity for forecasting is usually established by inference; if the model can accurately replicate base-year travel conditions, it is considered valid for the analysis of future year alternatives. The basic indicators of model validation for this project are the air and rail assignments. Comparing the counts with the estimated volumes indicates the validity of the network, trip tables, modal split model and trip assignment processes.



* Interchange to interchange distance
** Total highway distance

Figure 9-4
Trip Length Distribution Pennsylvania Turnpike and Total Person - Trips

9.3.1 Calibration Efforts

The first step in calibrating the modal split model and the trip assignment process was to use the model and the input discussed in the previous sections, including level of service data by mode and trip tables by purpose, to estimate the volume of trips by mode. The results indicated a significant overestimation of rail and air trip volume compared with the observed data.

The mode-bias coefficients for each mode were then changed to reflect transportation and socioeconomic characteristics for the corridor. The results indicated that both rail and air system totals were within acceptable accuracy. However, the number of short-distance trips was overestimated and the number of long distance trips was underestimated significantly. As a result, it was decided to include distance as a variable in the mode bias coefficients for the rail and air mode.

It was first assumed that rail and air mode-bias coefficients were a linear function of distance. After testing various coefficients, the best equations for mode-bias adjustments for air and rail were selected. In these equations, rail and air mode-bias coefficients are a function of the square root of trip length. The resulting calibrated mode-bias coefficients are illustrated in Table 9-7.

9.3.2 Comparisons with Observed Conditions

Basic source data from Amtrak, Civil Aeronautics Board and the Pennsylvania Turnpike were used to calibrate the mode choice model.[8,9,10] These data were used to estimate the mode-bias coefficients for the modal split model utility equations.

Four trip purposes were used in the mode choice model and each transportation mode was represented by one equation, called a utility equation. As the value of the modal utility increases, the probability of choosing that mode increases. The calibrated model was used to estimate the number of trips by mode, and these figures were compared to the number of observed trips. The volumes of estimated and observed trips were compared at several levels of aggregation to validate the model. A summary of the observed and estimated total trip volumes is shown in Table 9-8. The estimated and observed trip volumes were approximately the same as the observed trips within each common carrier mode. The number of estimated daily trips by trip purpose and by mode are summarized in Table 9-9. However, no data are available to compare with the estimated trip volumes by trip purpose. This test should be performed when data are available through the surveys proposed in Phase 2.

Estimated rail and air trips were aggregated by trip distance for further evaluation. As shown in Figures 9-5 and 9-6, both air and rail trips were slightly overestimated for the short-distance trips, (those of less than approximately 60 miles) and slightly underestimated for trips longer than 60 miles. However, both estimated rail and air trip length distribution curves follow expected patterns, and they match the observed curves reasonably well.

Detailed analysis of the estimated bus patronage was not performed due to the lack of data. However, the estimated total bus patronage was judged to be reasonable. Although comparisions of assigned highway volumes with observed volumes are meaningful for evaluation of the modeling process, it should be noted that the level of service data for auto users derived from the county level network for the modal split model was found to be accurate as discussed in the previous section.

TABLE 9–7

MODE-BIAS COEFFICIENTS USED IN UTILITY EQUATIONS

ORIGINAL COEFFICIENTS

Mode	Trip Purpose			
	Commuter	Business	Tourist	Other
Air	-1.313	-1.313	-3.435	-3.166
Bus	-3.159	-3.159	-1.797	-3.016
Rail	-2.461	-2.461	-3.288	-2.828
Auto	0	0	0	0

FINAL COEFFICIENTS

Mode	Trip Purpose			
	Commuter	Business	Tourist	Other
Air	$-5.613 + 0.403 \text{ x } (\text{Dist.})^{0.5}$	$-10.526 + 0.685 \text{ x } (\text{Dist.})^{0.5}$	$-12.535 + 0.600 \text{ x } (\text{Dist.})^{0.5}$	$-7.025 + 0.344 \text{ x } (\text{Dist.})^{0.5}$
Bus	-4.830	-4.820	-3.450	-4.416
Rail	$-6.855 + 0.403 \text{ x } (\text{Dist.})^{0.5}$	$-12.155 + 0.685 \text{ x } (\text{Dist.})^{0.5}$	$-13.240 + 0.600 \text{ x } (\text{Dist.})^{0.5}$	$-7.220 + 0.344 \text{ x } (\text{Dist.})^{0.5}$
Auto	0	0	0	0

TABLE 9-8

DAILY COUNTY-TO-COUNTY TRIPS BY MODE
Year 1980, Observed vs. Estimated

	Estimated	Observed	Estimated-Observed	Estimated/Observed
Air	3,360	3,170	+190	1.06
Bus	5,730	5,910	-180	0.97
Rail	2,240	2,270	-30	0.99
Auto	3,363,680	Not Available	-	-
Total	3,375,010	-	-	-

TABLE 9-9

ESTIMATED DAILY TRIPS BY TRIP PURPOSE
Year 1980

Mode	Commuter	Business	Tourist	Other	Total
Air	640	1,480	580	660	3,360
Bus	1,530	340	540	3,320	5,730
Rail	540	670	230	800	2,240
Auto	1,153,820	303,120	115,570	1,791,170	3,363,680
Total	1,156,530	305,610	116,920	1,795,950	3,375,010

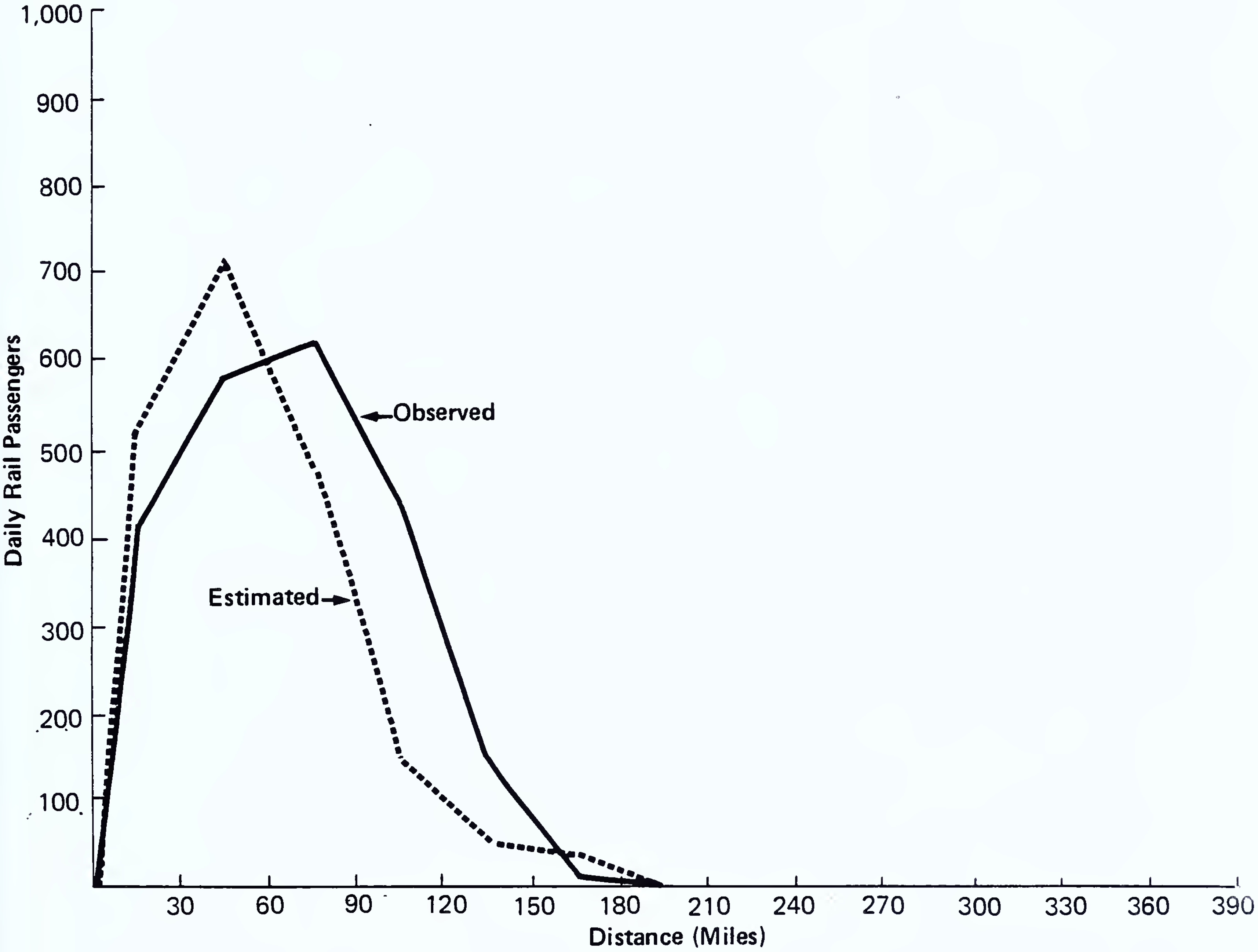


Figure 9-5
Rail Passenger Trip Length Distribution

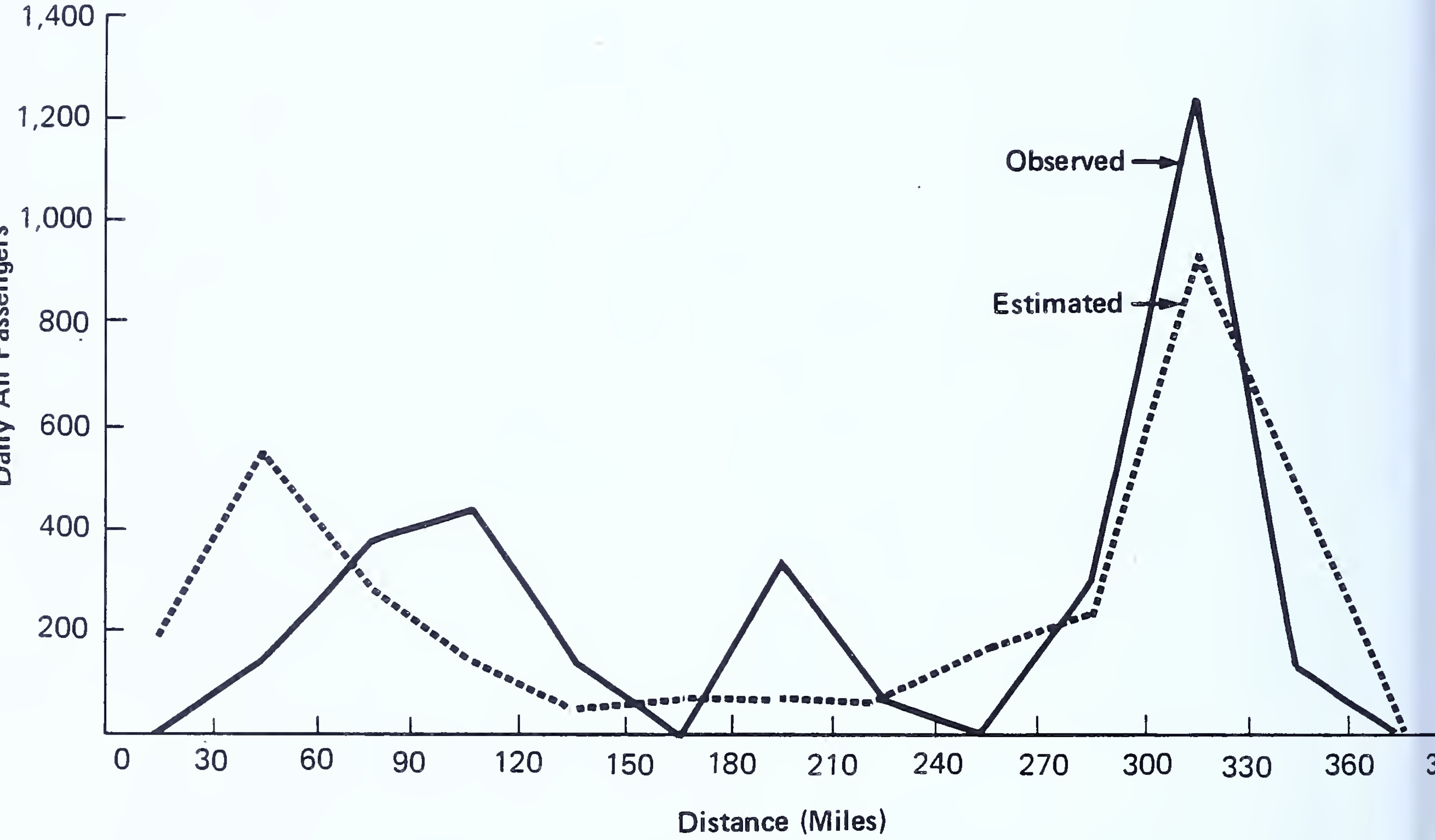


Figure 9-6
Air Passenger Trip Length Distribution

9.3.3 Sensitivity Testing

Sensitivity testing for the calibrated modal split model was performed to examine the applicability of the model for the HSR alternatives considered for this study. The sensitivity of the model to changes in input variables (cost, time, frequency and access) was tested against existing conditions for four trip lengths: 35 miles, 105 miles, 199 miles and 306 miles. Results are illustrated in Figures 9-7 through 9-10, which indicate that the elasticities for the calibrated modal split model are generally consistent with expectations. The cost elasticities, for example, are all less than one. As expected, intercity rail travel is more sensitive to travel time and cost than to access distance and frequency. Longer-distance travel is more sensitive than shorter-distance travel to all variables except access distance. Tourist trips are the least sensitive among the trip purposes to all input variables.

9.4 DEMAND ESTIMATES

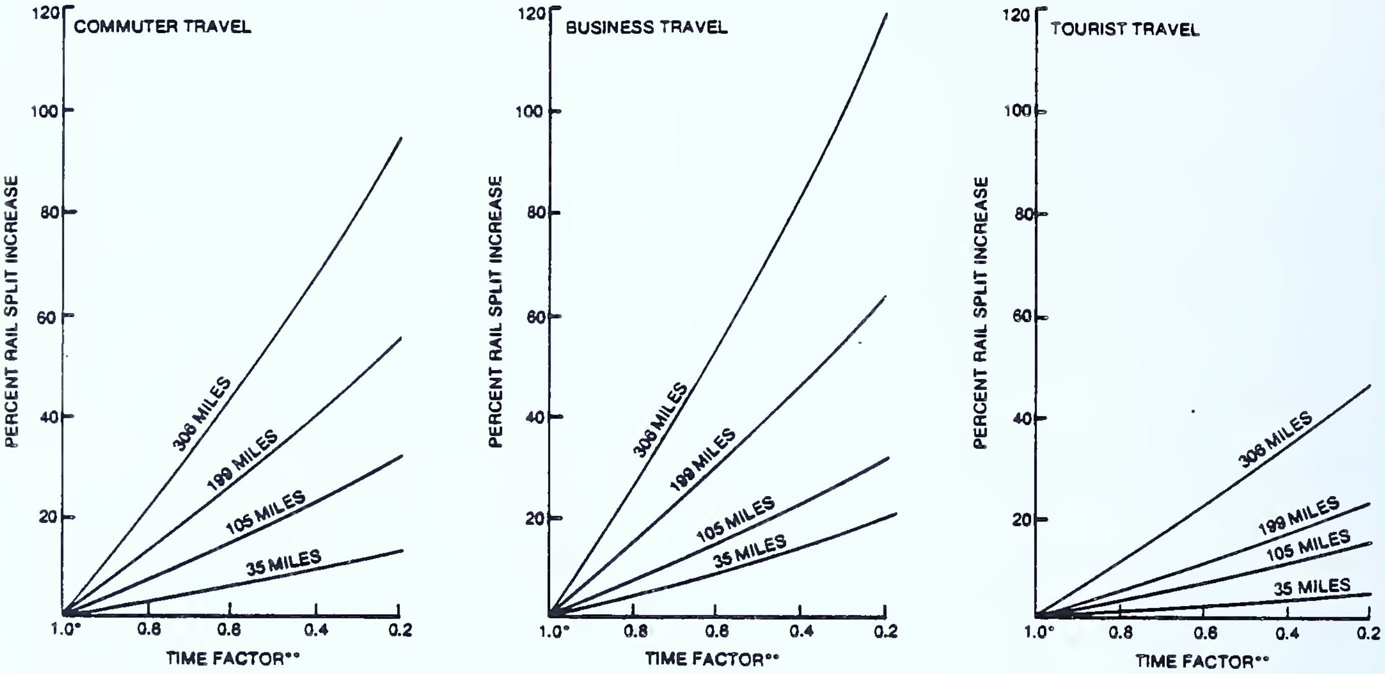
Establishing a planning range for demand estimates for the HSR systems required data describing the alternative systems and the study area for the year 2000. Socioeconomic data required for the modeling process are population, employment and income. Each alternative was coded using appropriate station-to-station distance and travel time. The calibrated model described in the previous section then was used to project a range of ridership (base- and high-demand scenarios) for each alternative HSR system for comparative analysis.

Existing rail station sites were used in each alternative system. Access distance for the HSR system was measured and then coded from each site to the surrounding counties' centers. Access time was calculated based on an average automobile speed of 30 mph. Existing SEPTA trains and Amtrak local trains are assumed to continue in operation as "feeder" trains to the HSR system. This gives rise to a "local rail" ridership category in the demand estimates.

Estimation of the number of person-trips by trip purpose for the projection year was performed by adjusting the base-year (1980) trips in a two-step process. The first step adjusts the existing person-trip volume based on changes in population and employment between the years 1980 and 2000. The second step factors these trips by the increased trip-making rate per person for the year 2000.

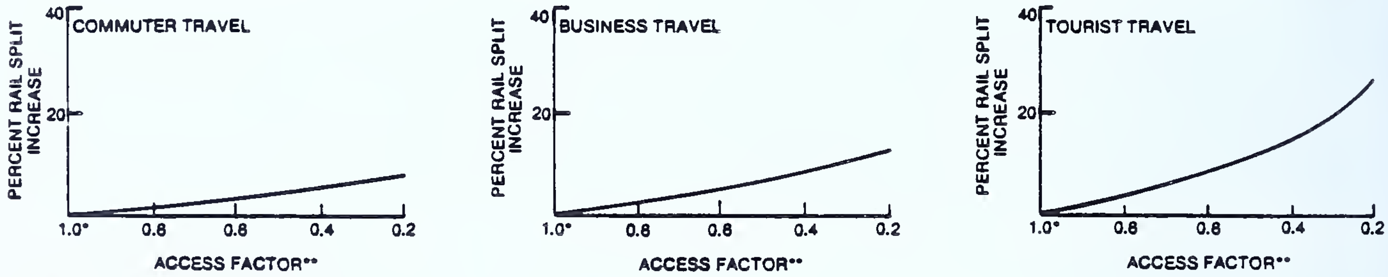
The growth in number of person-trips from 1980 to 2000 was performed separately for each trip purpose. The process for projecting commuter and business trips used both population and employment as variables to calculate a growth rate of each trip interchange, similar to the process discussed in Section 9.2.2. This growth rate was then applied to the 1980 trip volume by purpose to obtain the number of year 2000 trips. Tourist trips were factored based on changes in the origin zone population and the total tourist trip attractions for each zone. "Other" trips were projected based on changes in the origin and destination zones' population in a manner similar to that used for the commuter trip purpose. The socioeconomic data used in the projection processes are shown in Table 9-4.

The combination of changes in population and employment and an increase in trip-making rates results in a year 2000 total person-trip volume 42 percent greater than that used for 1980, or a compounded increase of 1.7 percent annually. The



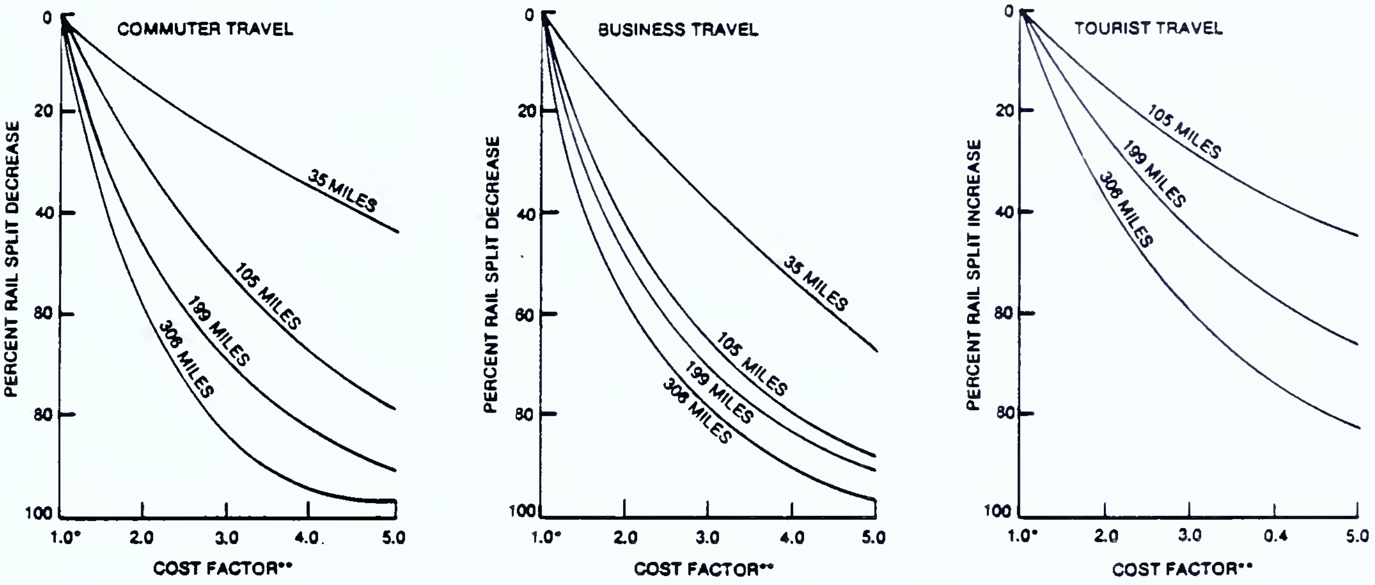
*EXISTING SYSTEM TOTAL TRAVEL TIME
**PROPOSED TOTAL TRAVEL TIME/
EXISTING TOTAL TRAVEL TIME

Figure 9-7
Modal Split Model Sensitivity to Travel Time for 4 Trip Lengths



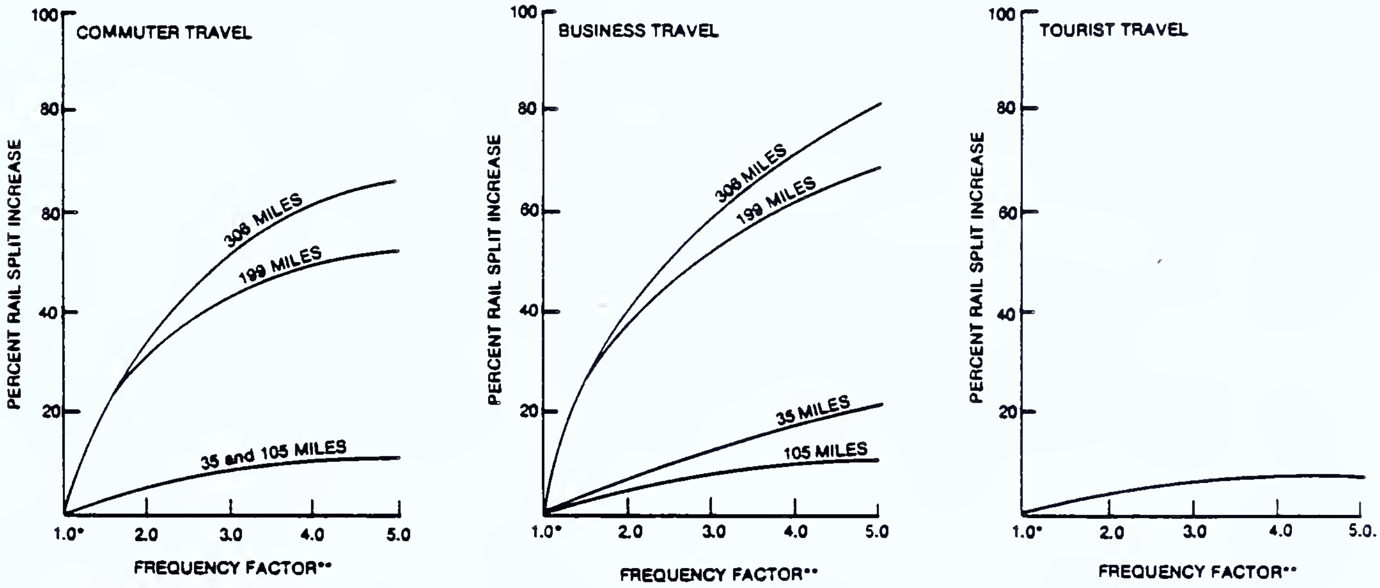
*EXISTING SYSTEM TOTAL ACCESS DISTANCE
**PROPOSED ACCESS DISTANCE/
EXISTING ACCESS DISTANCE

Figure 9-8
Modal Split Model Sensitivity to Access



*EXISTING SYSTEM TOTAL COST
**PROPOSED TOTAL COST/
EXISTING TOTAL COST

Figure 9-9
Modal Split Model Sensitivity to Cost for 4 Trip Lengths



*EXISTING SYSTEM FREQUENCY
**PROPOSED FREQUENCY/
EXISTING FREQUENCY

Figure 9-10
Modal Split Model Sensitivity to Frequency for 4 Trip Lengths

growth of the combined processes are shown in Table 9-10 by trip type. The increase in number of trips ranges from 35 percent for commuters to 50 percent for tourists.

9.4.1 Base-Demand Estimates

The estimates generated from the calibrated modal split model for each mode are presented in Table 9-11. Under this scenario, demand for rail services ranges from 13,170 person-trips per day for Alternative C to 16,900 person-trips per day for Alternative E. The rail patronage is separated into "local rail" and HSR service as indicated in Table 9-12. "Local rail" is defined as existing Amtrak intrastate service and excludes SEPTA commuter service. It can be seen that with increasing speeds represented in Alternatives D and E, a diversion of patronage from the existing local rail system to HSR will occur. Patronage on the local rail system drops by 890 daily riders from Alternative C to Alternative E. Table 9-13 provides the daily station-to-station trip tables for Alternatives C, D and E.

An estimate of patronage also was prepared to examine the impact of a station at State College where Pennsylvania State University's main campus is located. The estimate was based on statistics obtained from Penn State and the results of the patronage estimate for Alternative D without the State College station. The result indicates that an additional 650 daily HSR passengers in year 2000 would be generated due to shorter access time to and from Centre County, including State College.

9.4.2 High-Demand Estimates

The high-demand scenario model runs are summarized in Table 9-14. The number of estimated daily HSR trips ranges from 29,810 for Alternative C to 35,510 for Alternative E, a 130 percent average increase over the base-demand estimates. Table 9-15 summarizes daily patronage for local rail and HSR under the high-demand scenario.

9.4.3 Effect of Philadelphia-Atlantic City Service

Table 9-16 summarizes the number of additional trips per year that might result from riders connecting to a proposed Philadelphia-Atlantic City rail service to be operated by another entity. A range of ridership was estimated for each alternative, and each demand scenario. Because the number of future trips attracted by Atlantic City is difficult to estimate, the high and low values listed provide a range to represent the expected limits of rail ridership.

9.4.4 Impact of a Major Mid-State Resort Development

Table 9-17 shows the additional demand resulting from the mid-state resort development. Variations in total trip demand are accounted for by providing high and low estimates of ridership based on the limits of expected total trips generated by the proposed development.

9.4.5 Average Trip Length

The average trip lengths for each alternative are presented in Table 9-18. Passengers using existing Amtrak service make trips averaging 63 miles. Average

TABLE 9-10

DAILY PERSON-TRIPS BY PURPOSE
Years 1980 and 2000

Trip Purpose	Trips in Thousands			Percent Change
	1980	2000	Growth	
Commuter	1,156.5	1,561.7	405.2	35.0
Business	305.6	438.6	133.0	43.5
Tourist	116.9	175.5	58.6	50.1
Other	1,796.0	2,602.2	806.2	44.9
Total	3,375.0	4,778.0	1,403.0	41.6

TABLE 9–11

MODAL SPLIT SUMMARY
DAILY PERSON-TRIPS
Base Demand, Year 2000

Alternative	Air	Bus	Rail	Auto	Total
C	3,690	4,580	13,170	4,756,450	4,777,890
D	3,510	4,580	15,600	4,754,200	4,777,890
E	3,400	4,580	16,900	4,753,010	4,777,890

TABLE 9–12

DAILY RAIL PATRONAGE SUMMARY
Base Demand, Year 2000

Alternative	Local Rail	High Speed Rail	Total
C	2,020	11,460	13,480
D	1,640	14,100	15,740
E	1,130	16,070	17,200

TABLE 9-13
DAILY STATION-TO-STATION TRIP TABLES
Base Demand, Year 2000

ALTERNATIVE C

ORIGIN	DESTINATION Philadelphia	Paoli	Lancaster	Harrisburg	Altoona	Johnstown	Greensburg	Pittsburgh	TOTAL
Philadelphia	-	490	100	520	70	160	210	2,230	3,780
Paoli	460	-	10	60	10	20	20	250	830
Lancaster	130	10	-	50	30	50	50	140	460
Harrisburg	490	60	40	-	20	30	30	180	850
Altoona	70	10	70	40	-	40	50	40	320
Johnstown	140	20	60	40	60	-	40	40	400
Greensburg	130	10	140	40	10	60	-	730	1,120
Pittsburgh	2,390	270	150	140	20	10	720	-	3,700
TOTAL	3,810	870	570	890	220	370	1,120	3,610	11,460

ALTERNATIVE D

ORIGIN	DESTINATION Philadelphia	Paoli	Lancaster	Harrisburg	Altoona	Johnstown	Greensburg	Pittsburgh	TOTAL
Philadelphia	-	490	120	580	120	220	270	2,970	4,770
Paoli	460	-	10	60	10	30	30	330	930
Lancaster	140	20	-	20	60	60	50	190	540
Harrisburg	570	60	10	-	30	60	50	220	1,000
Altoona	120	10	40	60	-	230	10	60	530
Johnstown	210	20	50	40	260	-	30	80	690
Greensburg	220	30	80	80	50	50	-	720	1,230
Pittsburgh	2,950	330	190	190	30	70	650	-	4,410
TOTAL	4,670	960	500	1,030	560	720	1,090	4,570	14,100

ALTERNATIVE E

ORIGIN	DESTINATION Philadelphia	Paoli	Lancaster	Harrisburg	Altoona	Johnstown	Greensburg	Pittsburgh	TOTAL
Philadelphia	-	520	360	660	120	230	300	3,430	5,620
Paoli	510	-	40	70	10	30	40	380	1,080
Lancaster	420	50	-	20	50	80	70	230	920
Harrisburg	630	70	40	-	10	40	90	160	1,040
Altoona	130	10	50	50	-	240	30	40	550
Johnstown	210	20	60	50	260	-	40	70	710
Greensburg	270	30	60	100	30	30	-	750	1,270
Pittsburgh	3,310	370	220	190	20	70	700	-	4,880
TOTAL	5,480	1,070	830	1,140	500	720	1,270	5,060	16,070

TABLE 9-14

MODAL SPLIT SUMMARY
DAILY PERSON-TRIPS
High Demand, Year 2000

Alternative	Air	Bus	Rail	Auto	Total
C	2,770	4,580	29,810	4,740,730	4,777,890
D	2,580	4,570	33,490	4,737,250	4,777,890
E	2,490	4,570	35,510	4,735,320	4,777,890

TABLE 9-15

DAILY RAIL PATRONAGE SUMMARY
High Demand, Year 2000

Alternative	Local Rail	High Speed Rail	Total
C	4,990	28,100	33,090
D	1,960	31,990	33,950
E	1,710	34,680	36,390

TABLE 9-16

ESTIMATED ADDITIONAL RIDERSHIP
PHILADELPHIA-ATLANTIC CITY RAIL SERVICE
Year 2000

	Annual Ridership in Thousands					
	Alternative C		Alternative D		Alternative E	
	Low	High	Low	High	Low	High
Base-Demand Scenario	32	45	43	61	51	72
High-Demand Scenario	54	77	52	74	61	87

TABLE 9-17

ESTIMATED ADDITIONAL RIDERSHIP
MID-STATE DEVELOPMENT
Year 2000

	Annual Ridership in Thousands					
	Alternative C		Alternative D		Alternative E	
	Low	High	Low	High	Low	High
Base-Demand Scenario	110	370	110	370	130	430
High-Demand Scenario	130	430	130	430	150	500

TABLE 9-18

DAILY RAIL PASSENGER-TRIPS AND PASSENGER-MILES
Year 2000

	Alternative C		Alternative D		Alternative D—State College		Alternative E	
	Base Demand	High Demand	Base Demand	High Demand	Base Demand	High Demand	Base Demand	High Demand
Daily Passenger Trips	11,460	28,100	14,100	31,990	14,750	33,680	16,070	34,680
Daily Passenger Miles	2,257,100	5,576,000	2,700,500	5,977,000	2,920,500	6,466,560	3,330,900	6,941,200
Average Trip Length Per Passenger	197	198	192	187	198	192	207	200

trip lengths for high-speed rail are approximately three times as long. Alternatives D and E show a slight drop in average trip length between the base- and high-demand scenarios, indicating a greater growth of short-distance trips in relation to longer-distance trips.

9.4.6 Summary of Demand Estimates

Table 9-19 summarizes the annual ridership of Alternatives C, D, and E for both base- and high-demand scenarios. Potential additional ridership from availability of connecting Atlantic City rail service and the mid-state resort development are shown as well. For these additional sources of demand, the low end of the estimated ridership is associated with the base-demand scenario and the high end of estimated ridership is associated with the high-demand scenario.

TABLE 9-19

ANNUAL RIDERSHIP SUMMARY
Year 2000
(Thousands)

	Base Demand	High Demand
Alternative C		
Estimated Riders	4,183	10,256
Additional (Atlantic City)	32	77
Additional (Mid-State Resort)	110	430
Total	4,325	10,763
Alternative D		
Estimated Riders	5,146	11,676
Additional (Atlantic City)	43	74
Additional (Mid-State Resort)	110	430
Total	5,299	12,180
Alternative E		
Estimated Riders	5,866	12,658
Additional (Atlantic City)	51	87
Additional (Mid-State Resort)	130	500
Total	6,047	13,245

References

1 National Transportation Policies Through the Year 2000, National Transportation Policy Study Commission, Final Report, June 1979.

2 Ibid., page 44.

3 Ibid., page 44.

4 "Disaggregate Model of Mode Choice in Intercity Travel," Alan Grayson, Transportation Research Record 835, Transportation Research Board, 1981.

5 As reported in Reference 4.

6 Official Airline Guide—North American Edition, Official Airline Guides, Inc., Oakbrook, Ill., October 1983.

7 "Pennsylvania Statewide Origin and Destination Study, 1963, 1975, 1990," Edwards and Kelcey, Inc. for Pennsylvania Department of Highways, Bureau of Planning Statistics, Harrisburg, July 1966.

8 Amtrak Origin and Destination Data for the year 1983.

9 Origin-Destination Survey of Airline Passenger Traffic, Civil Aeronautics Board, 1981.

10 Pennsylvania Turnpike volume data, years 1982 and 1983, obtained from PennDOT.

11 Source: Columns 1, 2, 3, and 5--Regional Economics Projections Series, National Planning Association (NPA), Washington, D.C., 1984; Column 3--1980 Census, "Economic and Social Indicators," Summary Tape File 3, U.S. Bureau of the Census; Column 6--Year 2000 family income derived from NPA data and 1980 Census statistics.

12 Transportation and Traffic Engineering Handbook, ITE, 1982, page 265.

CHAPTER 10
FARES AND REVENUE FORECASTING

This chapter describes the investigation and analysis of existing fares, the preparation of demand model inputs, and the fare sensitivity tests performed. Passenger revenue forecasts are also presented. Additions to and deductions from these revenues have been made to account for other described aspects of system operation.

10.1 FARE DERIVATION

The demand model used in this study divides demand into four market segments: business, commuter, tourist and other. Travel is further partitioned into modes by a mode split-model in which cost is one of the independent variables. The existing fare structure for common carrier modes in the Pennsylvania Corridor was used as the basis for a cost function for the rail and bus modes and a fare matrix for the air mode. An air fare matrix was used in lieu of a cost function because of the large variations in fare levels and unsatisfactory results from regression analysis of the air fare data. Perceived auto travel costs were assumed to be $0.10 per vehicle-mile plus parking charges. An adjustment was made to reflect average auto occupancy by trip purpose.

The demand model output yields volume of total passenger-miles of travel for each mode. These ridership figures are multiplied by the average fare level for HSR to yield gross revenue. It should be emphasized that the fares used are "average fare levels." In effect, they represent the combined effective yield from an actual fare structure that would embody regular fares, first-class fares, and various excursion and promotional fares, all of which the operator would offer in order to maximize revenue yield. The average fare level used here is $0.16 per passenger-mile for all alternatives.

After calibrating the demand model, the sensitivity of the patronage projections to changes in fare level was analyzed. The 16-cent average fare level appears to be near the point of revenue maximization. As additional information becomes available through the surveys to be conducted in Phase 2, further investigation of fare sensitivity and revenue maximization will be performed.

10.2 REVENUE CALCULATIONS

10.2.1 Gross Revenue

Estimates of gross HSR passenger revenues are based on demand model projections of passenger-miles under each alternative and a uniform $0.16 per passenger-mile for all trips. Revenues were calculated for both the base- and high-demand scenarios.

10.2.2 Revenue Deductions

Several cost items are reflected as deductions from gross revenue rather than as operating costs; these items are travel agent commissions, food service losses and advertising costs.

Tickets for HSR service would be available both from the system operator and from independent travel agents. Based on current Amtrak experience and travel industry practice, it was assumed that one-third of the tickets would be sold by travel agents and that a 12 percent average commission would be granted. The deduction for travel agent commissions is therefore estimated as 4 percent of gross passenger revenue.

Another adjustment was made to account for the operation of on-train food service including the land-based commissary services which support it. The O&M cost estimate includes the charges for food service labor aboard HSR trains. Direct expenses for food, beverages and other supplies and related services are not included in O&M costs. Rather, it is assumed that the revenues from food and beverage sales on board will nearly cover the direct expenses, excluding labor. Since attractively priced on-board food and beverage service is a good marketing device, taking a small loss on such service is acceptable. Based on current Amtrak experience, a net deficit on food service operations of 2 percent of gross revenue has been deducted.

The cost of system advertising also has been reflected as a percentage deduction from gross revenue, rather than as an O&M cost. The figure used for the base- and high-demand scenarios, 3.5 percent, reflects current Amtrak expenditures, taking into consideration specific HSR operations. The Rail Passenger Service Act requires Amtrak to spend between 2 and 5 percent of revenues for promotion and advertising. Some additional advertising costs have been assumed to be provided by others, such as by Atlantic City resorts. In the case of the mid-state development study, 5 percent of the incremental revenue has been deducted for advertising purposes.

10.2.3 Other Revenues

The category of "other revenues" includes other operating revenues, auxiliary transportation revenues and non-operating revenues estimated from HSR operation. These additional revenue sources are described in the following paragraphs. The percentages used have been applied to both the base- and high-demand scenarios.

Other operating revenues come from offering special transportation services (charter services for football games, festivals, etc.), a small package service, checked baggage fees and mail fees. It is assumed that these services would be offered using existing HSR equipment, facilities and personnel and that any additional requirements would be the responsibility of outside concessionaires or contractors.

For example, an operator of ground-based parcel delivery service (e.g., Purolator) would find it attractive to use HSR trains rather than operate its own trunk line transportation system between Philadelphia and Pittsburgh. Such an operator would supply the personnel and equipment to operate the service. HSR system costs would be limited to those associated with cleaning the parcel areas on trains and stations, which costs have already been included as O&M costs. Based on current Amtrak and industry experience, an allowance of 3.3 percent of gross passenger revenues has been added to reflect mail and parcel revenues. It is recognized that the scope of the Pennsylvania Corridor limits the applicability of mail and parcel services; it would merely provide for a portion of the needs of a national or regional operator.

Auxiliary transportation revenues are those derived from station concessions and advertising. It has been assumed that no on-train advertising will be allowed. Based on mass transit and Amtrak experience, 1.3 percent of gross revenues has been estimated to result from such auxiliary transportation sources.

Non-operating revenues are those derived from the rental of space in stations. Although Amtrak derives 4 percent of its total revenues from station rentals, the amount of rental space available in the HSR stations is insufficient to support this level of activity. The available station space for each alternative has been multiplied by the average rate of $10 per square foot per year to reflect rental revenue. Joint development opportunities could significantly increase this source of revenue. The costs and revenue associated with such development should be further investigated in later stages of the project. The positive effects of such joint development are discussed in Chapter 14.

10.2.4 Possible Additional Revenue

Additional revenue may come from operating associated business enterprises or adding or relocating stations. One possibility for additional revenue is ridership resulting from connecting rail service between Philadelphia and Atlantic City. Potential revenues from this source have been calculated and included in gross revenues as a separate line item.

Another potential source of passenger revenues is the addition of a station at State College under the option in Alternative D. This service is projected to increase ridership and revenues. This revenue is included only under the Alternative D—State College option.

The remaining potential source of additional revenue investigated is associated with the mid-state resort development. The concept of this major development is a year-round entertainment, recreation and convention/conference complex, which would be built and operated by private developers at no cost to the HSR system. The revenues associated with increased ridership from this new destination also have been estimated.

It should be noted that the additional revenues are small with respect to the base revenues calculated. The revenues associated with Atlantic City service have been included in the base- and high-demand scenarios, and in the investment analysis discussed in Chapter 11. These revenues amount to less than one-half of 1 percent of net passenger revenues, however, and do not result in a distortion of the results.

The revenues associated with the potential mid-state development are used only in sensitivity tests, and are excluded from the investment analyses (for the base- and high-demand scenarios).

10.3 REVENUE SUMMARY

Tables 10-1 and 10-2 provide summaries of revenues for base- and high-demand scenarios, respectively. Both tables provide revenues for the first year of operation, through adjustments from demand projections for the year 2000. All revenues are expressed in terms of 1983 dollars.

TABLE 10-1

REVENUE SUMMARY
BASE DEMAND SCENARIO
(1983 Dollars in Millions)

Item	Alternative/First Year of Operation C 1995	 C-Electric 1995	 D 1997	 D-State College 1997	 E 199
o Passenger Fares	$112.36	$112.36	$139.77	$151.56	$179
o Other Operating Revenue: - Special Services (Football Games, Festivals, etc.), Baggage, Mail and Parcels	3.71	3.71	4.61	5.00	5
o Auxiliary Transportation Revenue (Station Concessions and Advertising)	1.46	1.46	1.82	1.97	2
o Non-Operating Revenue (Rental of Space in Stations)	.15	.15	.18	.19	
o Atlantic City Connecting Ridership	.37	.37	.53	.53	
Subtotal	$118.05	$118.05	$146.91	$159.25	$188
HSR Advertising Cost (3.5%)	4.13	4.13	5.14	5.57	6
Net Revenue	$113.92	$113.92	$141.77	$153.68	$181
Possible Additional Revenue (Mid-State Resort)	$ 2.35	$ 2.35	$ 2.43	$ 2.31	$ 2
HSR Advertising Cost (5%)	.12	.12	.12	.12	
Net Additional Revenue	$ 2.23	$ 2.23	$ 2.31	$ 2.19	$ 2
Range of Net Revenue	$113.92 116.15	$113.92 116.15	$141.77 144.08	$153.68 155.87	$181 184

TABLE 10-2

REVENUE SUMMARY
HIGH DEMAND SCENARIO
(1983 Dollars in Millions)

Item	Alternative/First Year of Operation				
	C 1995	C-Electric 1995	D 1997	D-State College 1997	E 1999
o Passenger Fares	$277.56	$277.56	$309.35	$334.68	$373.74
o Other Operating Revenue: - Special Services (Football Games, Festivals, etc.), Baggage, Mail and Parcels	9.16	9.16	10.21	11.05	12.33
o Auxiliary Transportation Revenue (Station Concessions and Advertising)	3.61	3.61	4.02	4.35	4.86
o Non-Operating Revenue (Rental of Space in Stations)	.15	.15	.18	.19	.23
o Atlantic City Connecting Ridership	.62	.62	.64	.53	.81
Subtotal	$291.10	$291.10	$324.40	$350.80	$391.97
HSR Advertising Cost (3.5%)	10.19	10.19	11.35	12.28	13.72
Net Revenue	$280.91	$280.91	$313.05	$338.52	$378.25
Possible Additional Revenue (Mid-State Resort)	$ 9.28	$ 9.28	$ 9.59	$ 9.12	$ 11.73
HSR Advertising Cost (5%)	.46	.46	.48	.46	.59
Net Additional Revenue	$ 8.82	$ 8.82	$ 9.11	$ 8.66	$ 11.14
Range of Net Revenue	$280.91 289.73	$280.91 289.73	$313.05 322.16	$338.52 347.18	$378.25 389.39

CHAPTER 11
FINANCIAL ANALYSIS AND PROJECTIONS

11.1 INTRODUCTION

Financial analysis is the critical step in a feasibility study when the data and information produced in previous steps are monetized (i.e., reduced to cost and revenue effects), and can be analyzed to determine if the proposed project is worthy of an investor's scarce resources. The financial analysis consists of the following steps:

- Identify the projected cost and revenue:
    - Initial capital investment
    - Operations and maintenance (O&M) expense after the project is commissioned
    - Revenues to be generated from ticket sales and other means
- Determine the timing of the cost and revenue components to estimate cash flow.
- Calculate the net benefit (or cost) of the project.
- Suggest whether the net benefits are sufficient to warrant the investment of resources from the standpoint of a public-sector or private-sector investor.

Cost and revenue estimates have been presented in Chapters 8 and 10, respectively. In this chapter, the financial analysis methodology, findings and a risk/return assessment are presented. The chapter concludes with a comparative evaluation of the alternatives and a preliminary assessment of financial feasibility.

11.2 METHODOLOGY

11.2.1 Cash Flow Projections

As noted, the financial analysis requires identification of projected annual cost and revenue streams, including capital investments and operating period costs and revenues. This provides an estimate of annual cash flows. The analysis includes only the direct costs and benefits inherent in the project. Related economic impact benefits (discussed in Chapter 14) are not monetized and are not included in the financial analysis.

Based on the results of Chapters 8 and 10, cash flows were projected for a 30-year operating period. As the construction period varies by alternative, the total time frame also varies by alternative. A 30-year operating time frame was chosen in part because vehicles are estimated to be replaced every 15 years. Thus, two full fleet replacement cycles are included in the projection period. In addition, extending the operating period for another 15 years would have a negligible impact on the alternatives' present value after discounting the cash flows for the time value of money.

The cash flow projections were inflated assuming a 7 percent inflation rate. It was assumed that this rate of inflation applies equally to all costs and revenues, excluding depreciation. Passenger revenues were increased each year by an additional 2 percent after the first year of operation to simulate projected growth in ridership.

The cash flow projections did not include any revenues from partial service during system phase-in. While this might seem to be a way to help offset construction period outlays, projections indicated that operating costs would exceed operating revenues during phase-in years.

11.2.2 Investment Analysis

As the potential financing alternatives may include either private or public financing, or both, an investment analysis was performed from both perspectives. The public sector perspective assumes that the HSR system is owned, financed and possibly operated by a public entity. In the second case, ownership, financing and operation are assumed to be a strictly private-enterprise undertaking. While the eventual HSR project may include both private and public sector involvement, this approach allowed an identification and examination of the range of conditions under which an HSR project could be developed.

Public and Private Sector Conditions

The fundamental distinction between the public and private sector perspectives is that the public sector analysis in this case excludes consideration of income taxes on cash flows. Thus, the computations of project returns are based strictly on the cost and revenue projections described above.

In the private sector case, tax considerations are introduced in the following ways. Under the Accelerated Cost Recovery System (ACRS) method of depreciation, tangible depreciable property except stations and facilities has an economic life of 5 years. Under the straight-line depreciation elections, which are available as alternates to the 5-year life, such property can be depreciated over 12 or 25 years. In all cases in this analysis, the straight-line (12- or 25-year) depreciation options were more favorable in terms of reducing taxes. The choice was that most favorable for the alternative — typically the 25-year option.

Stations and other fixed facilities have an 18-year economic life. This property has a straight-line election of 18 years, which was employed in all cases. Land is the only non-depreciable asset.

A tax rate of 46 percent of taxable income is assumed. Taxes are offset by investment tax credits (ITC) and deductions for net operating losses (NOL). ITC law requires that either the depreciable basis be reduced by 50 percent of the ITC or the ITC rate be reduced by 2 percentage points. In all cases, the ITC rate was reduced from 10 to 8 percent. ITCs are available in the year the capital asset is placed in service. For the purpose of calculating ITCs, we have assumed that all equipment is new and is placed in service in the first revenue-producing year. NOLs are available in the year after the operating loss is incurred. ITCs and NOLs may be carried forward for 15 years. It is assumed under the private financing analysis that the organizational structure in place would allow all available tax benefits to be used.

The impact of interest expense on taxes was not included in the investment analysis, as this expense cannot be determined until the financing plan has been developed. However, tax consequences will have a generally minor impact on computed returns. In some of the scenarios, no taxes are paid because of depreciation allowances and tax credits.

Discounted Return Calculations

The annual cash-flow projections were discounted to year 0, the beginning of the construction period. Two measures of project return were employed—net present value (NPV) and internal rate of return (IRR). Both measures consider the magnitude and timing of cash flows. The NPV indicates the estimated value of future cash flows at a given discount rate. The IRR method calculates the discount rate that makes the sum of all cash flows exactly equal to zero, and assumes intermediate cash flows are reinvested at the project rate.

NPV discount rates of 9 and 13 percent were used in the Pennsylvania Corridor analysis. Nine percent represents the estimated historical risk-free rate of return required by investors (2 percent) increased by a 7 percent inflation rate used in this analysis. Thirteen percent represents the risk-free rate of return currently employed by PennDOT in investment analysis (6 percent) increased by the 7 percent assumed inflation rate. Use of a risk-free discount rate allows for an explicit analysis of risk in a subsequent step.

11.3 FINDINGS

For each of the five alternatives (C, C-Electric, D, D-State College, and E), base- and high-demand scenarios were developed. The high-demand scenario incorporates increased passenger revenues, associated increased operating costs, and increased capital costs due to the purchase of additional vehicles.

11.3.1 Base- and High-Demand Projections

The cash-flow projections and investment analyses have been performed using a computer-generated spreadsheet which shows the financial performance of each alternative over the entire construction and 30-year operating period. An example of these projections is shown in Figure 11-1, which illustrates the results for Alternative C, high demand, private financing.[1]

This figure illustrates a number of the effects which the private financing assumption produces:

o ITCs become available in 1995, the first year of revenue service.

```
===========================================================================================================================
                                1987      1988      1989      1990      1991      1992      1993      1994      1995      1996      1997      1998
---------------------------------------------------------------------------------------------------------------------------
CAPITAL COSTS
  CONSTR & VEHICLES             9.07    109.84    388.27    522.26    663.71    657.79    421.62     90.00
  LAND                         19.23
  STATIONS                                                                                           62.37
  MAINT FACILITIES                                                                                   98.74

---------------------------------------------------------------------------------------------------------------------------
TOTAL CAPITAL                  28.31    109.84    388.27    522.26    663.71    657.79    421.62    251.11      0.00      0.00      0.00      0.00
===========================================================================================================================
REVENUES
  PASSENGER                                                                                                    584.22    636.80    694.11    756.59
  OTHER                                                                                                         28.50     30.50     32.63     34.92
  ADVERTISING COST                                                                                              21.45     22.95     24.55     26.27
  DEVELOPMENT
TOTAL REVENUES                                                                                                 591.28    644.35    702.19    765.23
---------------------------------------------------------------------------------------------------------------------------
EXPENSES
  O&M COST                                                                                                     296.15    316.88    339.07    362.80
  DEPR-5 YRS, 12 OPT                                                                                           238.55    238.55    238.55    238.55
  DEPR-18 YRS                                                                                                    8.95      8.95      8.95      8.95
TOTAL EXPENSES                                                                                                 543.65    564.38    586.56    610.30
---------------------------------------------------------------------------------------------------------------------------
TAXABLE INCOME                                                                                                  47.63     79.97    115.63    154.93

NOL CREDIT                                                                                                       0.00      0.00      0.00      0.00

TAXABLE INCOME NET NOL                                                                                          47.63     79.97    115.63    154.93

TAXES                                                                                                           21.91     36.79     53.19     71.27
TAX CREDITS                                                                                                     18.62     31.27     45.21     60.58
AFTER-TAX INCOME                                                                                                44.34     74.45    107.65    144.24

DEPRECIATION                                                                                                   247.50    247.50    247.50    247.50
---------------------------------------------------------------------------------------------------------------------------
CASH FLOW                     -28.31   -109.84   -388.27   -522.26   -663.71   -657.79   -421.62   -251.11    291.84    321.95    355.15    391.74
===========================================================================================================================
SUM                         26224.40
NET PV, 9%                   1102.91
NET PV, 13%                  -220.33
NET PV,15%                   -494.56
IRR                             0.12     11.95
---------------------------------------------------------------------------------------------------------------------------
ITC AVAIL                       0.73      8.79     31.06     41.78     53.10     52.62     33.73      7.20      0.00      0.00      0.00      0.00
ITC AVAIL SUM                   0.73      9.51     40.57     82.36    135.45    188.08    221.81    229.01    229.01    210.38    179.11    133.90
NOL CREDIT AVAIL                0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
NOL CREDIT SUM                  0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
===========================================================================================================================
```

Figure 11-1
Investment Analysis: Alternative C

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CAPITAL COSTS													
CONSTR & VEHICLES											1322.63		
LAND													
STATIONS													
MAINT FACILITIES													
TOTAL CAPITAL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1322.63	0.00	0.00
REVENUES													
PASSENGER	824.68	898.90	979.80	1067.98	1164.10	1268.87	1383.07	1507.54	1643.22	1791.11	1952.31	2128.02	2319.54
OTHER	37.36	39.98	42.77	45.77	48.97	52.40	56.07	59.99	64.19	68.68	73.49	78.64	84.14
ADVERTISING COST	28.11	30.08	32.19	34.44	36.85	39.43	42.19	45.14	48.30	51.68	55.30	59.17	63.31
DEVELOPMENT													
TOTAL REVENUES	833.93	908.79	990.39	1079.31	1176.22	1281.84	1396.95	1522.39	1659.11	1808.12	1970.51	2147.49	2340.37
EXPENSES													
O&M COST	388.20	415.37	444.45	475.56	508.85	544.46	582.58	623.36	666.99	713.68	763.64	817.09	874.29
DEPR-5 YRS, 12 OPT	238.55	238.55	238.55	238.55	238.55	238.55	238.55	238.55			110.22	110.22	110.22
DEPR-18 YRS	8.95	8.95	8.95	8.95	8.95	8.95	8.95	8.95	8.95	8.95	8.95	8.95	8.95
TOTAL EXPENSES	635.69	662.87	691.94	723.05	756.34	791.96	830.08	870.86	675.94	722.63	882.81	936.26	993.46
TAXABLE INCOME	198.23	245.93	298.44	356.26	419.88	489.88	566.87	651.54	983.17	1085.48	1087.70	1211.22	1346.91
NOL CREDIT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TAXABLE INCOME NET NOL	198.23	245.93	298.44	356.26	419.88	489.88	566.87	651.54	983.17	1085.48	1087.70	1211.22	1346.91
TAXES	91.19	113.13	137.28	163.88	193.14	225.34	260.76	299.71	452.26	499.32	500.34	557.16	619.58
TAX CREDITS	62.33	9.35	1.40	0.21	0.03	.00	.00	.00	.00	.00	89.94	13.49	2.02
AFTER-TAX INCOME	169.37	142.15	162.56	192.59	226.77	264.54	306.11	351.83	530.91	586.16	677.29	667.55	729.36
DEPRECIATION	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	8.95	8.95	119.17	119.17	119.17
CASH FLOW	416.87	389.65	410.06	440.09	474.26	512.04	553.61	599.33	539.86	595.11	-526.17	786.72	848.53
SUM													
NET PV, 9%													
NET PV, 13%													
NET PV,15%													
IRR													
ITC AVAIL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	105.81	0.00	0.00
ITC AVAIL SUM	73.33	11.00	1.65	0.25	0.04	0.01	.00	.00	.00	.00	105.81	15.87	2.38
NOL CREDIT AVAIL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NOL CREDIT SUM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 11-1 (continued)

Investment Analysis: Alternative C
High Demand—Private Sector

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
CAPITAL COSTS													
CONSTR & VEHICLES													
LAND													
STATIONS													
MAINT FACILITIES													
TOTAL CAPITAL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
REVENUES													
PASSENGER	2528.30	2755.85	3003.88	3274.22	3568.90	3890.11	4240.22	4621.83	5037.80	5491.20	5985.41	6524.10	7111.27
OTHER	90.03	96.33	103.08	110.29	118.01	126.27	135.11	144.57	154.69	165.52	177.11	189.50	202.77
ADVERTISING COST	67.75	72.49	77.56	82.99	88.80	95.02	101.67	108.78	116.40	124.55	133.26	142.59	152.57
DEVELOPMENT													
TOTAL REVENUES	2550.59	2779.70	3029.39	3301.53	3598.12	3921.36	4273.66	4657.62	5076.09	5532.18	6029.25	6571.01	7161.46
EXPENSES													
O&M COST	935.49	1000.98	1071.04	1146.02	1226.24	1312.08	1403.92	1502.20	1607.35	1719.86	1840.25	1969.07	2106.91
DEPR-5 YRS, 12 OPT	110.22	110.22	110.22	110.22	110.22	110.22	110.22	110.22	110.22				
DEPR-18 YRS	8.95												
TOTAL EXPENSES	1054.66	1111.20	1181.26	1256.24	1336.46	1422.29	1514.14	1612.41	1717.57	1719.86	1840.25	1969.07	2106.91
TAXABLE INCOME	1495.93	1668.50	1848.13	2045.29	2261.66	2499.07	2759.52	3045.21	3358.52	3812.31	4189.00	4601.94	5054.55
NOL CREDIT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TAXABLE INCOME NET NOL	1495.93	1668.50	1848.13	2045.29	2261.66	2499.07	2759.52	3045.21	3358.52	3812.31	4189.00	4601.94	5054.55
TAXES	688.13	767.51	850.14	940.83	1040.36	1149.57	1269.38	1400.80	1544.92	1753.66	1926.94	2116.89	2325.09
TAX CREDITS	0.30	0.05	0.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
AFTER-TAX INCOME	808.10	901.04	998.00	1104.46	1221.30	1349.50	1490.14	1644.41	1813.60	2058.65	2262.06	2485.05	2729.46
DEPRECIATION	119.17	110.22	110.22	110.22	110.22	110.22	110.22	110.22	110.22	0.00	0.00	0.00	0.00
CASH FLOW	927.27	1011.26	1108.22	1214.68	1331.52	1459.72	1600.36	1754.63	1923.82	2058.65	2262.06	2485.05	2729.46
SUM													
NET PV, 9%													
NET PV, 13%													
NET PV,15%													
IRR													
ITC AVAIL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ITC AVAIL SUM	0.36	0.05	0.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
NOL CREDIT AVAIL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NOL CREDIT SUM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 11-1 (continued)

Investment Analysis: Alternative C

- Beginning in 1995, operations produce revenues and positive cash flow. Taxable income is positive but ITC credits can be used to offset most of the tax liability through 1999. ITC credits earned from the construction period are depleted by 2004.

- In 2009, a cash outflow is sustained assuming the complete funding of a new vehicle fleet in this year, although taxable income continues to increase. (This is not dependent on private financing.) New ITC credits are generated with the acquisition of new vehicles. These credits are used to offset tax liability in 2009-2014.

- In 2015, tax benefits (ITCs and NOL carryforwards) are exhausted and the assumed 46 percent income tax is paid between 2015 and 2024, the close of the study period.

Similar spreadsheets were produced for each alternative, for each demand level, and for both public and private financing. The results are presented in Tables 11-1 and 11-2 which summarize the investment analysis results (NPV and IRR) from the private-sector and public-sector viewpoints, respectively.

In all scenarios, revenues are sufficient to cover operating costs. Only in the Alternative C, high-demand scenarios, however, are capital costs also fully covered by revenues, using a discount rate of 9 percent.

This finding is reiterated by the IRR analysis. Alternatives D through E, with high demand, show significant positive internal rates of return from the public-sector viewpoint; however, these rates are well below the 9 percent risk-free rate.

Under the base-demand scenarios, there is a small difference in the return generated from the public- and private-sector analyses. This is because under a private-sector structure, much of the tax liability is offset by depreciation and tax credits. The difference between the public- and private-sector perspectives is somewhat larger under the high-demand scenarios, but not greatly so because potential tax liabilities are offset by depreciation, ITCs, and NOL carryforwards. For example, in Alternatives C and E, full tax liability is not incurred until the 20th year of operations. Across all scenarios, the impact of taxes reduces returns to the private sector by only 0.5 to 2.7 percentage points.

11.3.2 Sensitivity Analysis

For each alternative, three sensitivity analyses were performed. These were the following:

- For the base-demand scenarios, the additional contingency of 25 percent of design and construction costs was added to the initial capital outlays. This represents a "worst case" sensitivity test.

- For the high-demand scenarios, additional ridership revenues accruing from the proposed mid-state development project were added.

- For the high-demand scenarios, passenger revenues were increased by 20 percent, representing either an ability to raise fares without loss of total

TABLE 11-1

INVESTMENT ANALYSIS SUMMARY: PRIVATE SECTOR
(negative values in parentheses)

	Alternative									
	C		C-Electric		D		D-State College		E	
	Base Demand	High Demand	Base Demand	High Demand	Base Demand	High Demand	Base Demand	High Demand	Base Demand	High Demand
Net Present Value (dollars in millions)										
@9% discount rate	(1,384)	1,103	(1,786)	888	(6,307)	(3,328)	(6,133)	(3,117)	(8,768)	(5,637)
@13% discount rate	(1,396)	(220)	(1,718)	(446)	(5,400)	(4,077)	(5,349)	(4,013)	(7,253)	(5,947)
Internal Rate of Return (%)	3.2	12.0	2.2	11.1	0.0	5.6	0.6	5.9	0.0	4.7

TABLE 11-2

INVESTMENT ANALYSIS SUMMARY: PUBLIC SECTOR
(negative values in parentheses)

	Alternative									
	C		C-Electric		D		D-State College		E	
	Base Demand	High Demand	Base Demand	High Demand	Base Demand	High Demand	Base Demand	High Demand	Base Demand	High Demand
Net Present Value (dollars in millions)										
@9% discount rate	(1,218)	2,830	(1,520)	2,560	(6,158)	(2,187)	(5,923)	(1,588)	(8,813)	(4,358)
@13% discount rate	(1,351)	447	(1,627)	181	(5,363)	(3,730)	(5,281)	(3,596)	(7,297)	(5,591)
Internal Rate of Return (%)	4.7	14.7	4.2	13.6	1.0	7.1	1.7	7.7	0.5	6.2

revenues, or additional ridership, or some combination of the two. This represents a "best case" sensitivity test.

These analyses broadened the range of returns represented by the base- and high-demand scenarios. In the public-sector analysis, the IRR decreased by 0.7 percentage points on the low end and increased up to 2.3 percentage points on the high end. In the private-sector analyses, the return decreased by up to 0.8 percentage point on the low end and increased up to 1.8 percentage points on the high end. In all alternatives, the effect of adding mid-state development revenues had a minimal impact on returns. Table 11-3 shows the impact of the sensitivity tests on IRR in detail, and Figure 11-2 shows pictorially the range of IRRs calculated for all scenarios under both public and private sector analyses.

11.4 RISK/RETURN ASSESSMENT

The analysis to this point has considered only the risk-free return required by private investors or the return to compensate for the loss of use of invested funds. When risk is introduced, an increment is required above the risk-free discount rate to reflect private investors' preference for safer investments.

There are many sources of risk in this project, including the risk of adverse swings of the economic cycle. The fundamental effects which stem from these diverse sources include:

- The risk associated with lower-than-projected revenues due to low ridership
- The risk associated with higher-than-projected capital costs
- The risk that the project may not be completed.

Some of these risks have been accounted for in the sensitivity analysis. Calculation of the returns from the base- and high-demand scenarios as well as the sensitivity tests indicated the range of possible outcomes for each alternative. This range of returns can be compared explicitly with an investor's preferences for risk and return. This trade-off will vary for each investor.

This type of project, however, can be characterized as sufficiently risky to require a return in excess of the prime lending rate, currently at 11.25 percent. Figure 11-3 shows the range of IRRs projected for each HSR alternative from the private-sector perspective together with the risk-free and prime lending rates. Given the requirement of a return in excess of the prime lending rate, the figure shows that none of the alternatives is projected to provide sufficient compensation to private investors for the risk level of the investment.

11.5 CONCLUSIONS

Alternative C provides the highest returns, both in terms of the relative returns, as measured by the IRR, and the absolute returns, as measured by NPV. Under similar conditions, Alternative C-Electric provides similar, although slightly smaller, positive returns. Both C Alternatives exceed the 9 percent risk-free rate of return. The only other alternative that exceeds this rate is Alternative D—State College under the "best case" sensitivity test and public sector viewpoint.

TABLE 11-3

SENSITIVITY ANALYSIS SUMMARY
INTERNAL RATES OF RETURN, percent

	Alternative									
	C		C-Electric		D		D-State College		E	
	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private
Base Demand + Additional Contingency	4.0	2.4	3.5	1.6	0.3	(0.3)	0.9	(0.1)	(0.2)	(0.6)
Base Demand	4.7	3.2	4.2	2.2	1.0	0	1.6	0.6	0.5	0.0
High Demand	14.7	12.0	13.6	11.1	7.1	5.6	7.7	5.9	6.2	4.7
High Demand + Mid-State Development	15.0	12.5	13.9	11.4	7.3	5.7	7.9	6.1	6.4	4.9
High Demand + Revenue Increase	17.0	13.8	15.8	12.9	8.6	6.8	9.2	7.2	7.7	5.9

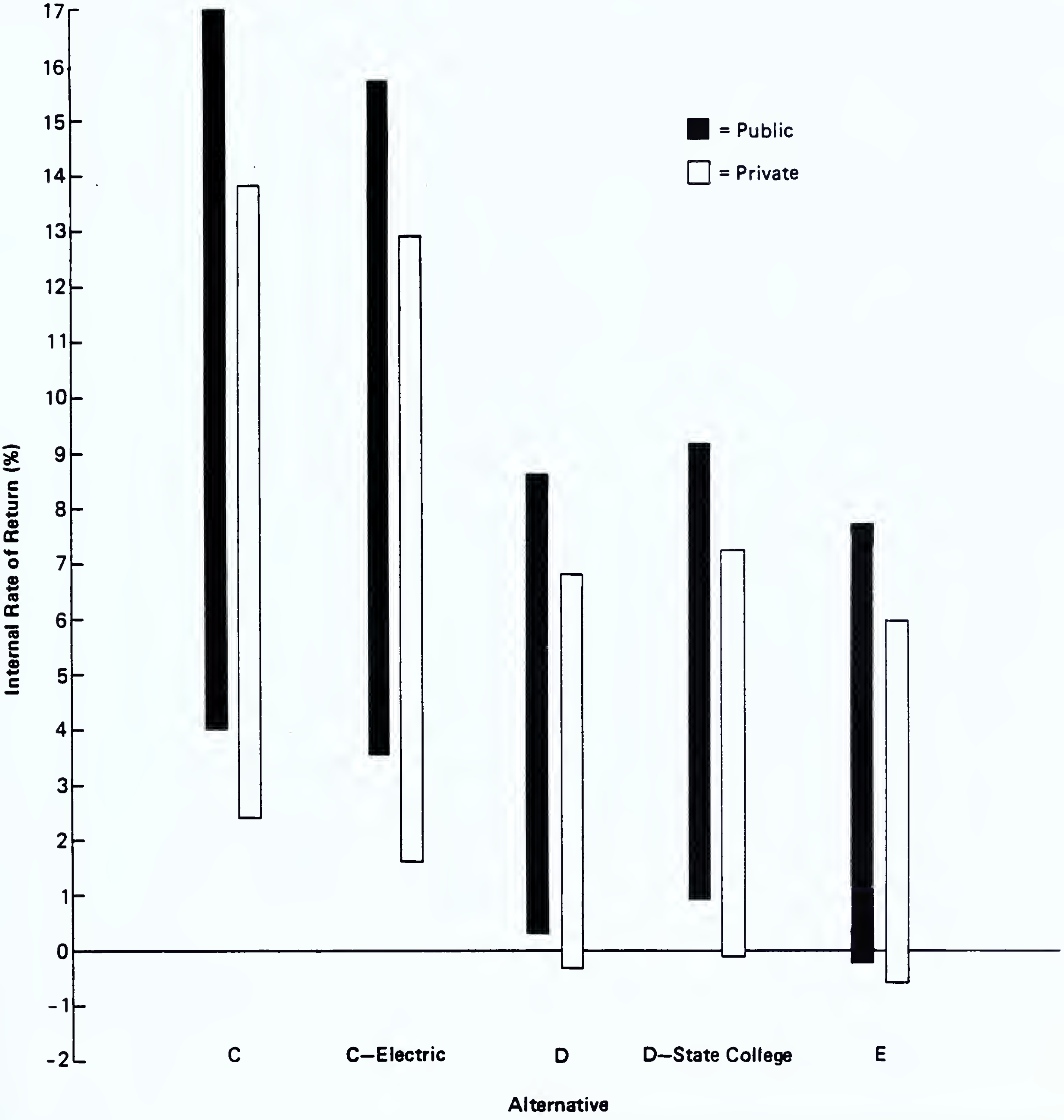


Figure 11-2

Range of IRRs by Alternative Including Sensitivity Tests Public and Private Sector Perspectives

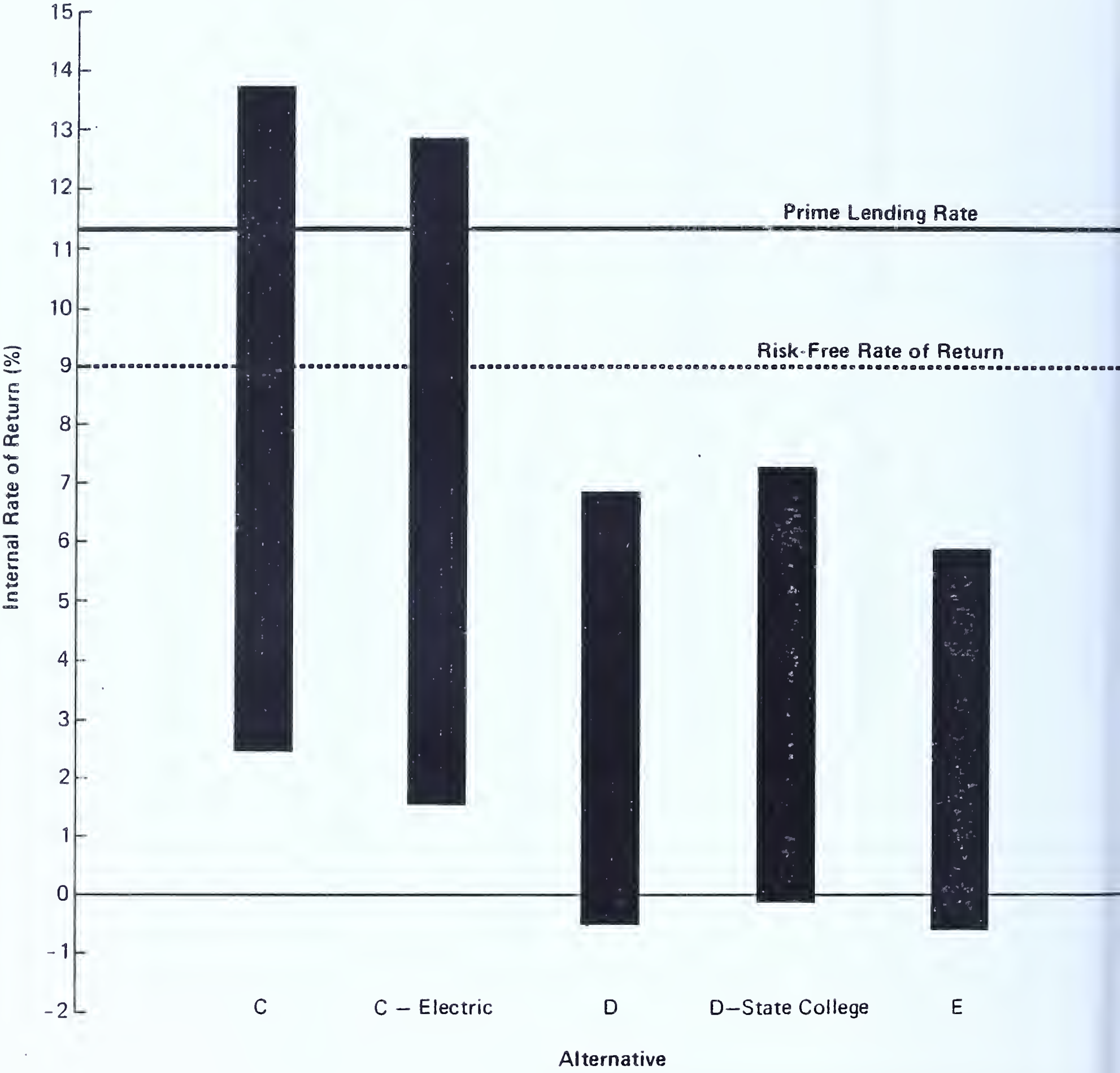


Figure 11-3
Range of IRRs by Alternative Compared to Benchmark Rates—Private Sector Perspective

Considering the risk premium that can be anticipated to be required by private investors, the investment analysis shows that projected HSR project returns are insufficient to generate enough capital from the private sector alone to implement any of the alternatives. A significant public sector role would be required.

From the public-sector perspective, only the C alternatives are projected to provide a return that exceeds the 13 percent hurdle rate which may be applied by the Commonwealth. This rate is exceeded only under the most optimistic assumptions with respect to capital costs and operating revenues. On the other hand, when one takes into account the significant economic benefits (which are excluded from this analysis) that may accrue to the state with HSR project implementation, as discussed in Chapter 14, a justification for public financial support of an HSR project can be made. Even with public support, however, a carefully structured financing package comprised of public- and private-sector sources of capital would be required. The following chapter discusses possible components of such a financing package.

References

1 The projections discussed in this chapter, made as of November 1984, should not be construed as statements of fact. The accuracy of any financial projection is dependent on the occurrence of future events which cannot be assured and, therefore, the actual results achieved during the projection period may vary from the projections.

CHAPTER 12
FINANCING OPTIONS

In the Chapter 11 financial analyses we found that, from both the public- and private-sector perspectives, while the revenues in all scenarios covered operating costs, in most cases they were insufficient to cover capital costs. When capital costs were covered, the returns were inadequate to cover the risk premium that would be demanded by private investors.

Nevertheless, by taking a combined public/private sector approach and accounting for the economic impact benefits accruing to Pennsylvania, some financing options may be possible. In this chapter, we explore these options, focusing on Alternative C, because it is the most likely of the five alternatives to be financed.

12.1 FINANCING OPTIONS

In order to maximize the potential for financing, the fixed-cost burdens of the project must be minimized. A high level of fixed costs for debt service or lease payments will saddle the venture with the need to generate large volumes of revenue simply to cover its capital investment. The impact of the initial capital investment burden on returns is made clear by calculating the returns generated without associated construction costs (e.g., operating revenues less operating costs and vehicle capital costs, not including taxes). For Alternative C, these range from 11 to 14.5 percent for the base- and high-demand scenarios, respectively.

Fixed costs can be minimized in two ways: (1) by maximizing the equity investment, and (2) by borrowing at favorable rates. Equity investment may be generated from a variety of sources, including:

- sales of stock to the public or in private placements
- investments made through limited partnerships
- acceptance of an ownership interest in the project by vendors and suppliers as partial payment for capital items sold
- grants from public bodies
- donation of assets by public bodies or private sources
- other capital contributions made by groups benefiting from the project, such as property owners, hotels, theme park operators and others.

Favorable interest rates can be obtained through borrowing at preferential rates from vendors, using tax-exempt debt or obtaining loan guarantees from public or private sources.

Maximization of equity and obtaining favorable interest rates can be achieved through a variety of mechanisms, described below.

12.1.1 Vendor Participation

Vendor participation is a term used to describe certain terms of sale offered by a manufacturer or supplier. It includes sources of export credits from foreign countries, leaseback arrangements, barter provisions, discounts, direct credit and almost any technique used by a producer of a good or service to help a purchaser finance its acquisition.

Vendors enter into such arrangements in order to make sales that would not otherwise be possible. For example, McDonnell Douglas has conducted an active program to lease its new DC-9 jetliners on favorable terms to airlines that might not otherwise be able to make the investment, thus competing aggressively with other manufacturers. In another case, the Metropolitan Transportation Authority (MTA) of New York recently completed several acquisitions of new rolling stock on which foreign vendors were able to offer credit terms better than those available from conventional sources.

Particular vendors may offer very favorable terms to break into a particular market or to establish the performance record of their products. New product models and technology are frequently tested in revenue service in the railroad industry to help eliminate design flaws and establish performance criteria. Intermodal equipment and locomotives are prime examples.

In the case of HSR projects, vendors represent one of the few groups that can look beyond the investment constraints identified in the previous chapter and realistically assess the risks inherent in a particular project. As a result of their sophistication, as well as their desire to make a sale and establish a showcase for their product, vendors are likely to offer financing on beneficial terms.

A project in Pennsylvania also would be in a favorable position to negotiate terms because of the large scale of the purchases involved and its early entry in the field. Any one of the major contracts awarded for the Pennsylvania project could keep a vendor and its team of subcontractors busy for several years. Furthermore, ongoing requirements for spare parts, equipment modernization and eventual replacement products would far exceed the value of the initial procurements. Finally, successful revenue operation in Pennsylvania would serve as a vital marketing aid in bidding on future contracts in other states.

The forms of vendor participation have been limited only by law and the imaginations of the parties. Recent international aircraft sales have involved barter trades, technology exchanges, assembly site agreements and other features. Features that could be applied in Pennsylvania include:

- acceptance of stock in the HSR venture for a portion of the equipment purchase price

- lease/purchase or equipment trust financing on favorable terms

- credit guarantees from vendors or financial institutions associated with vendors for debt issued by the HSR venture

- substantial discount of the purchase price to cut initial investment requirements

12.1.2 Tax Benefits

Potential investors in a Pennsylvania HSR program may be attracted by the tax benefits of depreciation, ITCs and initial NOLs. Private corporations with minimal taxable income or public bodies, such as public transit agencies, have little need for the tax benefits arising from potential investments. Lease arrangements can enable investors seeking tax shelters to, in effect, purchase the benefits from organizations that do not need those shelters. The net effect of the transaction is to reduce the purchase price by the amount received in the sale of the tax benefits. The actual percentage of the investment that can be recovered through this mechanism varies, depending on the depreciation classification of the asset, timing of the transaction, complexity of the deal, credit rating of the lessee and liquidity of the assets. In addition, recently enacted legislation would restrain opportunities for accelerated depreciation if the project is financed with industrial development bonds. A more detailed discussion of the intricacies of federal tax law is contained in Appendix C.

Railroads such as Amtrak and CSX have sold tax benefits on locomotive investments, while Norfolk and Western has purchased tax benefits. Most major transit systems have used special safe harbor leasing provisions in federal law to sell tax benefits on the local share of their bus acquisitions. Pennsylvania's Department of Transportation has led the industry in coordinating a statewide safe harbor lease transaction involving several hundred buses for many transit properties.

The nature of the tax benefits and the profit potential of the venture will have to be better assessed in order to evaluate strategies to maximize the tax benefits of HSR investments. As described, these benefits can be "sold" directly to reduce initial capital outlay requirements or factored into devising the ownership structure of the enterprise as a technique for attracting private equity investment. For example, rather than buying the tax benefits of the assets, investors might purchase equity through limited partnerships or other mechanisms that allow tax advantages to be realized in the early years of the investment until anticipated profits begin to flow.

12.1.3 Value Capture and Land Development

A benefit created by the construction of railroads and fixed guideway public transportation systems is an increase in property values along the route, particularly at stations. Private railroads have capitalized on these benefits through the sale, lease and joint venture development of land and air rights of their properties. Publicly-owned mass transit systems have captured higher property values through similar sales, leases and joint ventures of operating properties, as well as through the creation of special benefit and tax increment districts. A special benefit district was created in Berkeley, California, in 1966 to pay for $12 million of bonds issued for improvements to Bay Area Rapid Transit (BART), and Denver uses a special assessment district to pay for maintenance costs of its new transit mall.

Because construction of an HSR system in Pennsylvania is likely to yield similar benefits, public and private owners can incorporate a financing component that uses enhanced real estate values to help reduce inital capital costs and/or to contribute to operating revenues. With the system's terminal points in major urban centers and potential for spin-off development and tourism at intermediate stops, value-capture arrangements could make a significant contribution to financing the venture. In addition, if the real estate involved is owned by the venture, it could represent a tangible asset that could be used to secure credit for initial construction of the rail lines and stations.

12.1.4 Tax-Exempt Revenue Financing

Tax-exempt industrial revenue financing allows a private entity to finance a capital investment with bonds whose interest is not subject to federal income tax. As a result, interest costs can be reduced by as much as 25 percent below rates on comparable taxable debt. Recently enacted legislation imposes very strict limitations on industrial development bonds. These limits affect the scale of any single bond issue and the nature of the activities that can be financed. So-called "mass commuting facilities" are exempted from many of these limits, but there is doubt as to whether such a designation would apply to a Pennsylvania HSR project in the absence of new legislation (see Chapter 13).

In a similar project, the California Legislature has authorized $1.25 billion in industrial revenue bonds for high speed rail development. Tax-exempt debt of this type is repaid from revenues generated by the project. The bonds are debt obligations of the entity on whose behalf they are issued, are not repaid from state or local government funds, and do not carry a guarantee of repayment by the State or any other governmental body.

12.1.5 Grants and Subsidies

A strong case can be made for public financing of some portion of an HSR project, based on the substantial benefits which will accrue to the Pennsylvania economy if the project were to go forward. The benefits are quite consistent with the economic development objectives put forth in the State Planning Board's strategic planning document.[1]

There are several options for publicly subsidizing the construction costs. These include the following:

- Direct Grants—issuance of bonds to be repaid from general revenues or dedicated taxes to pay for initial investments
- Credit Support—use of special low-interest loans or loans guaranteed by state agencies
- Land - use of eminent domain to assemble land and/or development rights
    - potential write-downs in land costs required for stations or rights-of-way and/or allowing land held by the state to be encumbered for debt to build the system

  - development rights to key parcels could be granted to the venture, or special taxing districts could be used to pay for station costs.

- Parking—investments in parking facilities required for station areas can be financed through public authorities, eliminating a potential source of debt from the balance sheet of the venture.

12.1.6 Adjustments in Project Scope

It is possible that by exercising its powers of regulation and eminent domain, the Commonwealth could control the scope of an HSR venture. In issuing a charter or development rights, the final definition of the project could influence its costs and its ability to attract private investment.

The barriers to financing HSR in Pennsylvania are not unlike those which confronted the railroad industry at its inception—the technology was new, markets were untested, the equipment had limited liquidity, large initial investments were needed, and fixed costs were high. In some cases, governments adjusted the project scope by granting land or other tangible assets to attract private investors. These assets could be mortgaged to generate cash for construction. Land could also be developed for industrial, mining, or agricultural purposes to generate freight traffic, or as tourism destinations to attract passengers.

Improvements to Adjacent Freight Lines—In the case of HSR, some changes in project scope may prove advantageous in terms of generating cost savings, as well as attracting private capital. For example, in Pennsylvania, right-of-way may be shared extensively with existing railroads, requiring land purchase or easements which could prove expensive. However, by expanding the scope of the project to include improvements to adjacent freight tracks, overhead clearances, communications and signaling, and even electrification, the purchase or lease costs could be reduced in exchange for significant benefits offered to the railroad without large increases in marginal construction costs.

Conveying Additional Assets or Development Rights—In other instances, shifting the scope of the project could add value to the rights to develop an HSR project in Pennsylvania. Because of the marginal level of returns, equity may have to flow from public sources, as outlined in the previous section on grants and subsidies. Conveying additional assets or development rights with the HSR charter offers an alternative or complementary approach for the state to make these contributions.

An example could involve assembling large blocks of land, beyond those needed for operating purposes, at stations and selected tourist attractions and including the property (or its development rights) in the charter for the HSR venture. With this asset, theme park developers, real estate joint ventures and major firms in the travel and hospitality industries could be attracted. Such developers could, in turn, attract a high level of management and marketing skill and offer strong financing capability. The added project value and enhanced development capability could increase the chances for success.

Multiple Use of Rights-of-Way--Railroads such as CSX and Amtrak have entered into agreements for joint use of rights-of-way for telecommunications networks. Fiber-optic cables are being laid on Amtrak's Northeast Corridor and in the Conrail portion of the Pennsylvania Corridor. The railroads will receive rental income as well as the capacity needed to meet internal communications requirements. CSX has formed a joint venture with a telecommunications firm to develop a fiber-optic network. Similar possibilities for generating income from secondary uses of rights-of-way exist for the Pennsylvania HSR project.

While limiting the state's exposure for subsidies and offering the potential of magnified economic development spin-offs, broadening the scope of the venture also carries disadvantages. There is cost to the state to assemble the land or obtain the rights it may seek to include in an HSR charter. These outlays must be compared to a straight cash subsidy or other incentive mechanism. The state also bears the risk that the subsidiary ventures may not prove as profitable as anticipated and that additional subsidies will be required later in the project life. Similarly, there is the risk that the developers will concentrate their resources and energies on the high-value portions of the charter and not give full attention to maintaining quality HSR services. As a result, potential shifts in the scope of the project must be carefully evaluated as cost and revenue projections are refined later in the course of study.

12.2 POTENTIAL FINANCING PACKAGE

Described below is a hypothetical financing package for Alternative C using the mechanisms described above in a combined public/private sector approach to implementing HSR service in Pennsylvania. This package entails a significant financial note for the state, and is predicated on the substantial benefits to the Pennsylvania economy which HSR service would provide. Under this alternative, 8,000 permanent jobs and $140 million in annual personal income could be added to the economy. State tax revenues could increase by $95 million during construction and about $15 million annually could flow to the state thereafter.

The financing package consists of the following features:

- A private enterprise would construct, own, and operate the HSR service.

- The Commonwealth would provide the enterprise with a $350 million loan at 7 percent interest with a term of 38 years.

- Other institutions would provide loans to the enterprise in the amount of $1.1 billion at 13 percent interest and a term of 38 years. The low interest rate would be obtained through vendor loan guarantees.

- An additional 15-year, 13 percent loan would be provided in 2009 for replacement of the vehicle fleet. The present value of this loan would be $250 million under the base-demand scenario and $300 million under the high-demand scenario.

- The enterprise would make an equity investment of $350 million under the base-demand scenario and $390 million in the high-demand scenario, from its own resources.

- Funding for stations would be provided by real estate developers and local governments with an interest in promoting station-area development.

- The enterprise would be so structured as to have sufficient other interests to take full advantage of all ITCs and NOLs as they become available, subject to the at-risk limitations.

This financing package was applied to the Alternative C base- and high-demand scenarios to illustrate its application and results. The financing terms are quite favorable to the enterprise, but such terms may in fact be required for financing to move forward.

Figure 12-1 presents a pro forma cash flow statement for the enterprise under the Alternative C high-demand scenario, for a 30-year operating period.[2] The analysis begins with the first year of construction and includes projected interest and principal payments based on the loan terms described.

As shown in Figure 12-2, the enterprise would be able to service debt and earn a profit under the Alternative C high-demand scenario as indicated by the positive net present values within a zero- to 19-percent range of discount rates. Whether these returns are sufficient to attract equity financing will depend on the comparison of these returns with those of other similarly risky ventures. Excess market returns represent the returns provided to equity investors to compensate them for the riskiness of the project. In other words, these are the returns generated after accounting for inflation (7 percent) and the required risk-free rate of return (2 percent). The average annual excess market return to the equity investors equals 14.0 percent in the Alternative C high-demand scenario. So long as equity investors believe this 14.0 percent return rate is adequate to compensate for the riskiness of the venture, the investment would be profitable.

For the Alternative C base-demand scenario, this number drops to -2.5 percent and means that revenues are insufficient to cover capital and operating costs after accounting for inflation and the risk-free rate of return. Stated another way, the base-demand scenario generates a return on investment lower than the assumed inflation rate.

12.3 CONCLUSIONS

While a variety of financing mechanisms are available, the magnitude of returns for the HSR alternatives studied limits the types of financing that can be successfully employed. As noted, the financing package must be carefully structured to take advantage of both public-sector support and available tax benefits. Thus, a public/private sector approach will be required. In addition, debt repayment terms favorable to the enterprise will be necessary.

The financing concept described contains the following elements:

- a public/private sector approach

- maximum use of ITCs and NOLs

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CAPITAL COSTS													
CONSTR & VEHICLES	9.07	109.84	388.27	522.26	663.71	657.79	421.62	90.00					
LAND	19.23												
STATIONS													
MAINT FACILITIES								98.74					
TOTAL CAPITAL	28.30	109.84	388.27	522.26	663.71	657.79	421.62	188.74	0.00	0.00	0.00	0.00	0.00
REVENUES													
PASSENGER									584.22	636.80	694.11	756.58	824.67
OTHER PASS REV									28.50	30.50	32.63	34.91	37.36
ADVERTISING COST									21.45	22.95	24.56	26.28	28.12
OTHER REV	236.00	252.00	234.00	197.00	136.00	68.00	22.00	0.00					
TOTAL REVENUES	236.00	252.00	234.00	197.00	136.00	68.00	22.00	0.00	591.27	644.34	702.18	765.22	833.92
EXPENSES													
O&M COST									296.15	316.88	339.06	362.80	388.19
DEPR-5 YRS, 12 OPT									238.55	238.55	238.55	238.55	238.55
DEPR-18 YR									5.49	5.49	5.49	5.49	5.49
INTEREST	167.50	167.14	166.75	166.31	165.83	165.30	164.71	164.05	163.33	162.52	161.63	160.63	159.53
TOTAL EXPENSES	167.50	167.14	166.75	166.31	165.83	165.30	164.71	164.05	703.51	723.43	744.72	767.46	791.75
TAXABLE INCOME	68.50	84.86	67.25	30.69	-29.83	-97.30	-142.71	-164.05	-112.24	-79.09	-42.54	-2.24	42.16
TAXES	31.51	39.03	30.94	14.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.39
AFTER-TAX INCOME	36.99	45.82	36.32	16.57	-29.83	-97.30	-142.71	-164.05	-112.24	-79.09	-42.54	-2.24	22.77
PRINCIPAL	3.75	4.11	4.51	4.94	5.42	5.96	6.55	7.20	7.93	8.73	9.63	10.62	11.73
DEPRECIATION									244.03	244.03	244.03	244.03	244.03
ITC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	229.01	0.00	0.00	0.00	0.00
NOL CR (NET)	0.00	0.00	0.00	0.00	13.72	44.76	65.65	75.46	51.63	36.38	19.57	1.03	0.00
CASH FLOW (1840 '87)	1844.94	-69.13	-356.46	-510.63	-685.24	-716.29	-505.23	-284.53	404.50	192.59	211.43	232.20	255.07
SUM	21985.27												
NET PV, 9%	2067.92												
INVESTMENT	390.00												
ROI	13.95												
ITC GENERATED	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	229.01	0.00	0.00	0.00	0.00
NOL CREDIT GENERATED	0.00	0.00	0.00	0.00	29.83	97.30	142.71	164.05	112.24	79.09	42.54	2.24	0.00
NOL CREDIT USED					29.83	97.30	142.71	164.05	112.24	79.09	42.54	2.24	
NOL CUM AVAIL					0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NOL LIMIT					29.83	127.13	269.84	433.89	546.13	625.22	667.76	670.00	670.00

Figure 12-1
Pro Forma Cash Flow Statement

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
CAPITAL COSTS													
CONSTR & VEHICLES										1322.63			
LAND													
STATIONS													
MAINT FACILITIES													
TOTAL CAPITAL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1322.63	0.00	0.00	0.00
REVENUES													
PASSENGER	898.89	979.80	1067.98	1164.09	1268.86	1383.06	1507.54	1643.22	1791.10	1952.30	2128.01	2319.53	2528.29
OTHER PASS REV	39.97	42.77	45.76	48.97	52.40	56.06	59.99	64.19	68.68	73.49	78.63	84.14	90.03
ADVERTISING COST	30.08	32.19	34.44	36.86	39.43	42.20	45.15	48.31	51.69	55.31	59.18	63.32	67.76
OTHER REV													
TOTAL REVENUES	908.78	990.38	1079.30	1176.21	1281.82	1396.93	1522.38	1659.09	1808.09	1970.48	2147.46	2340.34	2550.56
EXPENSES													
O&M COST	415.37	444.44	475.55	508.84	544.46	582.57	623.35	666.99	713.68	763.63	817.09	874.28	935.48
DEPR-5 YRS, 12 OPT	238.55	238.55	238.55	238.55	238.55	238.55	238.55			110.22	110.22	110.22	110.22
DEPR-18 YR	5.49	5.49	5.49	5.49	5.49	5.49	5.49	5.49	5.49	5.49	5.49	5.49	5.49
INTEREST	158.30	156.93	155.41	153.71	151.81	149.70	147.34	144.70	141.76	310.41	302.47	293.55	283.50
TOTAL EXPENSES	817.70	845.40	874.99	906.58	940.30	976.30	1014.72	817.18	860.92	1189.75	1235.26	1283.53	1334.69
TAXABLE INCOME	91.09	144.97	204.31	269.63	341.52	420.63	507.65	841.92	947.17	780.74	912.20	1056.81	1215.87
TAXES	41.90	66.69	93.98	124.03	157.10	193.49	233.52	387.28	435.70	253.33	419.61	486.13	559.30
AFTER-TAX INCOME	49.19	78.28	110.33	145.60	184.42	227.14	274.13	454.64	511.47	527.41	492.59	570.68	656.57
PRINCIPAL	12.96	14.32	15.85	17.55	19.44	21.56	23.91	26.55	29.49	65.51	73.45	82.37	92.42
DEPRECIATION	244.03	244.03	244.03	244.03	244.03	244.03	244.03	5.49	5.49	115.70	115.70	115.70	115.70
ITC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NOL CR (NET)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CASH FLOW (1840 '87)	280.26	307.99	338.51	372.08	409.01	449.62	494.25	433.57	487.46	-745.03	534.84	604.01	679.86
SUM													
NET PV, 9%													
INVESTMENT													
ROI													
ITC GENERATED	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	105.81	0.00	0.00	0.00
NOL CREDIT GENERATED	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NOL CREDIT USED													
NOL CUM AVAIL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NOL LIMIT	670.00	670.00	670.00	670.00	670.00	670.00	670.00	670.00	670.00	670.00	670.00	670.00	670.00

Figure 12-1 (continued)
Pro Forma Cash Flow Statement
Alternative C—High Demand

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
CAPITAL COSTS												
CONSTR & VEHICLES												
LAND												
STATIONS												
MAINT FACILITIES												
TOTAL CAPITAL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
REVENUES												
PASSENGER	2755.84	3003.86	3274.21	3568.89	3890.09	4240.20	4621.81	5037.78	5491.18	5985.38	6524.07	7111.23
OTHER PASS REV	96.33	103.07	110.29	118.01	126.27	135.11	144.56	154.68	165.51	177.10	189.49	202.76
ADVERTISING COST	72.50	77.57	83.00	88.82	95.03	101.68	108.80	116.42	124.57	133.29	142.62	152.60
OTHER REV												
TOTAL REVENUES	2779.66	3029.36	3301.49	3598.08	3921.32	4273.62	4657.57	5076.04	5532.12	6029.19	6570.94	7161.39
EXPENSES												
O&M COST	1000.97	1071.03	1146.01	1226.23	1312.06	1403.91	1502.18	1607.33	1719.85	1840.24	1969.05	2106.89
DEPR-5 YRS, 12 OPT	110.22	110.22	110.22	110.22	110.22	110.22	110.22	110.22				
DEPR-18 YR												
INTEREST	272.20	259.47	245.15	229.02	210.86	190.40	167.34	141.37	112.10	79.11	41.92	.00
TOTAL EXPENSES	1383.38	1440.73	1501.38	1565.47	1633.14	1704.52	1779.74	1858.92	1831.95	1919.35	2010.98	2106.89
TAXABLE INCOME	1396.28	1588.63	1800.11	2032.61	2288.18	2569.09	2877.83	3217.12	3700.17	4109.84	4559.96	5054.50
TAXES	642.29	730.77	828.05	935.00	1052.56	1181.78	1323.80	1479.87	1702.08	1890.53	2097.58	2325.07
AFTER-TAX INCOME	753.99	857.86	972.06	1097.61	1235.62	1387.31	1554.03	1737.24	1998.09	2219.31	2462.38	2729.43
PRINCIPAL	103.72	116.45	130.77	146.90	165.06	185.53	208.58	234.55	263.82	296.81	334.00	375.92
DEPRECIATION	110.22	110.22	110.22	110.22	110.22	110.22	110.22	110.22	0.00	0.00	0.00	0.00
ITC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NOL CR (NET)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CASH FLOW (1840 '87)	760.49	851.63	951.51	1060.93	1180.77	1312.00	1455.67	1612.91	1734.27	1922.51	2128.38	2353.51
SUM												
NET PV, 9%												
INVESTMENT												
ROI												
ITC GENERATED	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NOL CREDIT GENERATED	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NOL CREDIT USED												
NOL CUM AVAIL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NOL LIMIT	670.00	670.00	670.00	670.00	670.00	670.00	670.00	670.00	670.00	670.00	670.00	670.00

Figure 12-1 (continued)

Pro Forma Cash Flow Statement

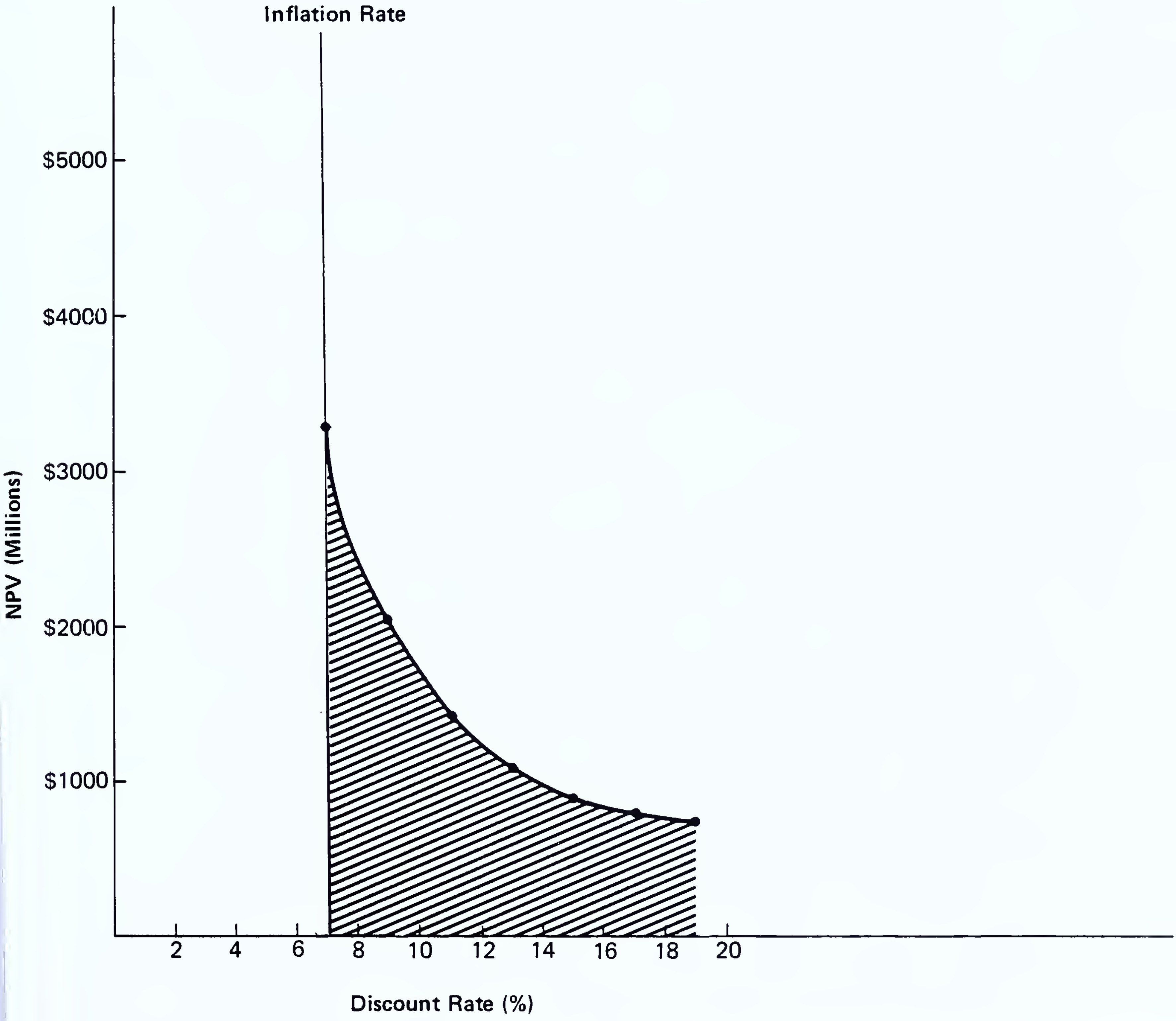


Figure 12-2
NPV vs Discount Rate
Alternative C—Financing Package

- vendor support through loan guarantees
- favorable interest and repayment terms
- public-sector financial support through favorable loan terms.

When this package is applied to the alternative with the most favorable investment returns, Alternative C, the results are mixed. As illustrated in Figure 12-2, revenues from the high-demand scenario can cover both operating costs and debt service and produce a profit. Revenues under the base-demand scenario, however, are insufficient to cover debt service after operating costs are paid, and net losses are incurred over the project life.

References

1 Choices for Pennsylvanians--Final Report, Pennsylvania State Planning Board, Commonwealth of Pennsylvania, Harrisburg, December 1980.

2 The projections discussed in this chapter, made as of November 1984, should not be construed as statements of fact. The accuracy of any financial projection is dependent on the occurrence of future events which cannot be assured and, therefore, the actual results achieved during the projection period may vary from the projections.

CHAPTER 13
INSTITUTIONAL CONSIDERATIONS

13.1 INTRODUCTION

This chapter investigates how a Pennsylvania HSR system might be organizationally structured, and also discusses the relationships among the system operator and other public and private bodies, collectively the "institutional" issues.

The resolution of key institutional issues has a fundamental effect on the financing of the system, and indeed financing will likely determine the exact organizational structure. As more definition emerges in Phases 2 and 3 of the feasibility study, the institutional analyses will become more specific.

This report discusses generally the kinds of entities that can be created to own and operate the system; how each affects other decisions, such as encouragement of private investment; and how these entities might be affected by and interact with existing institutions.

13.2 APPROACH

Here are some of the questions that system organizers will face:

- What is the projected capital cost of the system, and of each of its major cost components (real estate, rights-of-way, track, stations and operating equipment)?
- Is the system expected to become operational all at once or in stages? What dates are targeted for construction and for commencement of service?
- Is the system expected to produce revenues sufficient (or more than sufficient) to fund operations and debt service? Will tax revenues or appropriations will be available to supplement fare and other revenues?
- To what extent and on what terms can or must elements of the system be leased from other parties?
- What will be the cost, if any, of reaching an accommodation with Amtrak? With Conrail?
- Will the state exercise the power of eminent domain to facilitate the acquisition of the property or other rights required by the system?
- Will the entity that owns the real property over which the system operates be exempt from local property tax either (1) as a state governmental entity, or (2) pursuant to special legislation that both exempts it from property tax and does not violate the state constitutional requirement of uniformity.

Answers to some of these questions have been provided as a result of the Phase 1 feasibility study; others will be provided in Phases 2 and 3, and through the development of a dialogue between the Pennsylvania project and the institutions discussed in this chapter.

Lacking firm answers to all the questions posed, the study team has attempted to suggest an organizational structure designed to maximize the system's ability to be self-supporting. Accomplishing this objective will be a challenge and will demand the continued interest of the Legislature.

It has been assumed that no direct financial assistance (grants, loans, or loan guarantees) would be available from the federal government. Favorable rulings from the Internal Revenue Service (IRS) or favorable legislation concerning the system's eligibility for certain tax benefits have not been ruled out in this analysis, however.

13.3 ORGANIZATIONAL STRUCTURE

13.3.1 Management and Ownership

Three alternative structures for management and ownership have been considered. Although discussed separately below, the system probably would be developed in stages, evolving from wholly public to a combination of public and private ownership and control. There are many ways in which the structures discussed may be "fine tuned" during the various phases of planning, financing, construction and operation. Decisions affecting the structure of management and ownership cannot be made in a vacuum; financing, in particular, will have an important effect on, and in turn be affected by, management and ownership structures.

Private Management and Ownership

If an alternative system is projected to be profitable, the most appropriate scenario is that of private management and ownership. There are a number of potential configurations involving one or more private entities, including limited partnerships created to take advantage of the tax benefits potentially available through the system's acquisition and use of major capital assets. The principal drawback to employing an entirely private structure at the outset is one of timing; the bulk of the federal tax incentives that might induce a private company or group of investors to develop the system would not become available until rail service begins. Moreover, such benefits are available only for portions of the system in actual operation.

Given this timing problem, it is questionable whether private investors would commit enough money fully to finance the system, in the absence of some type of state sponsorship, commitment or involvement in the initial phases of the project, unless the downstream profitability is projected to be very large indeed.

Public Management and Ownership

At the other end of the spectrum, a system could be owned and managed solely by the Commonwealth, either through an operating authority or commission created for this purpose. Public management and ownership may be the only feasible structure for a system that is projected to be unprofitable, but worthwhile nonetheless because of the important economic and social benefits that it could generate.

Exclusive public ownership and operation of the system would have the advantage of giving the Commonwealth control over all phases of the system's development and operation. At the same time, however, it would impose the full cost of financing both construction and any operating deficits on the Commonwealth. The possibility of employing indirect federal subsidies (through the use of private entities able to take advantage of federal income tax benefits such as deductions for depreciation, interest, other operating expenses, and ITCs) would be eliminated.

Some of these disadvantages could be mitigated by recognizing that it may be appropriate to have different levels of public ownership and management of the system at different stages of the project. For example, state involvement at the initial stages of planning and construction, as contemplated by the Pennsylvania Rural and Intercity Common Carrier Surface Transportation Assistance Act[1], would facilitate the system's acquisition of any necessary real property by eminent domain. It should be noted, however, that current law does not permit the acquisition of rights-of-way of a "transportation company" without such company's consent. The term transportation company includes Amtrak and Conrail, which are owners, respectively, of the Philadelphia-Harrisburg and Harrisburg-Pittsburgh rights-of-way. As the system enters the operating phase, the private HSR entity could assume primary responsibility for the system's financing and operations with continued state cooperation in approving fares and generating any necessary supplemental revenues to fund operations. This leads to the hybrid- or staged-ownership approach.

Public/Private Management and Ownership

A structure contemplating public as well as private participation from the outset may be politically more acceptable than a structure which imposes the full financial responsibility upon the Commonwealth. At the same time, it could afford the system the benefits of state involvement, including the power of eminent domain. A joint public/private structure also could maximize federal tax "subsidies" for the system while ensuring that the public interest is fully and fairly served. This type of structure might be particularly appropriate if the alternative system is projected to be profitable, but not highly profitable.

The structuring of such joint public/private participation would have to be carefully arranged to avoid the possible loss of federal tax benefits. For example (as explained more fully in Appendix C), public ownership or leasing of certain assets may eliminate federal tax benefits (depreciation and ITCs) while private ownership or leasing of certain assets may preclude the use of certain tax-exempt bond financing. Under the recently passed Tax Reform Act of 1984, the opportunities to structure a public/private venture with federal income tax subsidies have been diminished. Specific tax legislation favoring HSR systems is needed in several areas. Proposals for such legislation will be developed in Phase 3.

13.3.2 Autonomy of the System

The owning and operating entities, whether public or private, can be structured to make them more or less independent of the political process, and to permit the system to develop more or less autonomously of other transportation services actually or potentially available in the Commonwealth.

A project of this magnitude will require broad-based, bipartisan political support and will undoubtedly raise wide-ranging and contradictory expectations. An autonomous agency or relatively unregulated private body would be in a better position to establish priorities and to resist, for example, pressure to locate stations or arrange schedules according to political rather than economic factors or to allocate contracts to Pennsylvania companies without regard to efficiency considerations. On the other hand, if the owning and operating entities are too autonomous, they might set their priorities without regard to the possibilities for maximizing secondary benefits to the Pennsylvania economy or for integrating HSR development with that of other forms of transportation.

Decisions about how to finance and manage the system may determine how independent it can or must be and what forms the owning and operating entities can take. If the Commonwealth is expected to provide a significant amount of support in the form of capital and other assistance, the system will need to be accountable to its citizens. Conversely, if large amounts of private capital are to be raised, the investors will expect to have some control over the entities they are funding.

13.3.3 Relations with Amtrak

Whatever entity owns and operates the system must deal with Amtrak. Amtrak asserts the right to license entities that wish to offer rail passenger service in a market area already served by Amtrak and to exact fees for granting those licenses. While it has taken the position that fees will be set at reasonable levels that will not cause any otherwise-viable HSR project to cease to be workable, Amtrak also insists that it is not limited to charging fees which reflect damage done to it through a loss of ridership to the competing line. It argues, instead, that it is permitted to charge a license fee that reflects the value of the license to the licensee. It has proposed that, for profitable systems, the fee be calculated to include a percentage of the profits.

Amtrak's claims are both statutory and contractual. Its statutory claims are based on section 401(c) of the Railroad Passenger Service Act of 1970 (RPSA)[2], which provides:

> ". . . no railroad or any other person may, without the consent of (Amtrak), conduct intercity rail passenger service over any route over which the Corporation is performing scheduled intercity rail passenger service pursuant to a contract under this section."

Section 401(c) is the only federal statutory provision that explicitly limits the right of entities other than Amtrak to provide rail passenger service. It is a narrow provision, which applies only to intercity rail passenger service, over a route "over which (Amtrak) is performing scheduled intercity rail passenger service," where Amtrak is operating pursuant to a contract entered into under Section 401. It does not apply to routes where Amtrak is operating pursuant to Section 402 or to lines which are outside Amtrak routes. It applies only to routes designated as part of the basic Amtrak system. That basic system has been defined to include the original end point routes designated by the Secretary of Transportation in 1971, as modified by the 1979 Final Route Structure Plan. Those entities that wish to operate over routes regularly serviced by Amtrak are required by Section 401 to get the consent of Amtrak. Nowhere in Section 401 does it say that Amtrak may unreasonably refuse to give its consent, or may exact payment in return for giving its permission.

Amtrak asserts that "route" means market area. Thus Amtrak asserts a right to license and exact fees from a parallel line, even one operating between cities not serviced by Amtrak, if those cities are within what Amtrak sees as its "market."

Neither the statute itself, the legislative history of 401(c), judicial opinions, nor administrative regulations or decisions explicitly support Amtrak's position. It is doubtful that at the time it passed RPSA Congress intended to give such broad authority to Amtrak. Congress' intention was to prevent the continued deterioration and wholesale abandonment of rail passenger service in America. Congress never considered the relationship between Amtrak and the new rail entities, which are now proposing to invest significant amounts of capital to offer new HSR services. No such entities were on the horizon 13 years ago.

Further, one of the 1980 Amendments to RPSA[3] appears to be inconsistent with Amtrak's broad reading of Section 401(c). Section 655 directs the Secretary of Transportation to encourage private-sector development of rail passenger corridors. Pursuant to this mandate, the Secretary is to take all necessary legal steps to remove institutional and legal barriers to private development of rail passenger corridors. But, as interpreted by Amtrak, the 401(c) consent requirement could have a crippling effect on private investment in HSR--an effect that is at odds with the 1980 law.

In addition, portions of an Agreement between Amtrak and Conrail[4] provide that Conrail will not "without the prior written consent of Amtrak, operate (or seek the common carrier authority to operate) or provide any regularly scheduled Intercity Rail Passenger Service" except in accordance with the Agreement and certain other exceptions not relevant here. Amtrak interprets the non-competition clause to be an exclusivity clause, precluding Conrail from permitting others to operate passenger service over its tracks without Amtrak's written permission. (The Agreement applies between Harrisburg and Pittsburgh; Amtrak itself owns the lines between Harrisburg and Philadelphia.)

Amtrak may oppose any attempt to establish HSR service in Pennsylvania except under license from it. It will be necessary, therefore, for the owning or operating entities either to reach some accommodation with Amtrak or to seek to limit Amtrak's authority to license. Accommodation might take the form of the purchase of a license from Amtrak on the best terms available, or a contract to have Amtrak serve as the operator of equipment over HSR lines. Because the Pennsylvania Corridor and Amtrak's Northeast Corridor will feed into and benefit each other, as Amtrak officials have recognized, it would be wrong to assume at this stage that accommodation will be difficult or result in onerous conditions being imposed on the system.[5]

If Amtrak's claims to licensing authority become in fact an impediment to the development of HSR, those claims could be defeated through litigation. Such a course is likely to be expensive and time-consuming and might have a chilling effect on the ability of HSR groups to secure necessary financing.

It may well be preferable to look to Congress rather than the courts to resolve this problem—either by repealing 401(c) or by seeking legislation clarifying Amtrak's rights under that section. Repeal of 401(c) would remove all doubts about Amtrak's ability to hinder the development of HSR through its claimed licensing authority. At the same time, repeal may well also eliminate Amtrak's rights where it is appropriate that Amtrak have such rights. Alternatively, Amtrak's 401(c) powers could be left intact, but high-speed rail exempted from the provision by adding:

> (d) Where a state, railroad or other entity seeks to provide a dedicated high-speed rail system, Section (c) does not apply.

If repeal or exemption is thought to be undesirable or unachievable, legislation may be enacted to help clarify the boundaries on Amtrak's authority, particularly in situations under which it can refuse its consent, the measure of its right, if any, to seek compensation from a competing line, and the definition of the term "route." The amended Section 401(c) might read:

> (c) Except as provided in Section 545(b) of this title concerning autoferry service, states, railroads or other persons may conduct intercity rail passenger service over any route over which the Corporation is performing scheduled intercity rail passenger service pursuant to a contract under this section, unless the Corporation can demonstrate that such service will have an adverse impact on the overall profitability of the basic system. If the Corporation demonstrates that there will be such an overall adverse impact, it will be entitled to a payment from the state, railroad or other person operating such service, limited to an amount necessary to offset the adverse impact caused by a loss of ridership attributable to competition from that service. For the purposes of this section, route is defined as the right-of-way. The state, railroad or other person may offset such Corporation claim of loss by demonstrating that its operations have had a beneficial effect on the Corporation.

As amended, Section 401(c) might help to promote the goal of passenger rail corridor creation announced in the RPSA 1980 Amendments.

13.3.4 Relations With SEPTA

SEPTA operates commuter rail service in the five-county area in and around Philadelphia, including service on the Pennsylvania Corridor between Paoli and Philadelphia. SEPTA claims an operating easement on that line and may dispute any arrangement between Amtrak and the system that fails to recognize its asserted rights, at least to the extent that the arrangement would disrupt current and currently projected commuter service.

SEPTA owns the right-of-way between Market East station and the west bank of the Schuylkill River. Potential use of this segment would require an agreement with SEPTA or the use of Amtrak's rights on this segment.

13.3.5 Relations With Conrail

Conrail operates rail freight service throughout Pennsylvania and owns the existing track and right-of-way between Harrisburg and Pittsburgh. Conrail has contractual obligations to Amtrak relating to intercity rail passenger service between Harrisburg and Pittsburgh and contractual rights to use Amtrak's lines between Harrisburg and Philadelphia. The system would obviously need to reach an accommodation with Conrail to the extent that the system would want to use Conrail property or would involve Conrail's contractual rights and obligations to Amtrak. Negotiations with Conrail may be complicated by the current uncertainty concerning the future status of that railroad.

13.4 INTERACTION WITH REGULATORY BODIES AND LABOR

Railroads traditionally have been subjected to heavy regulation in the United States. Rates must be approved by either state commissions or the Interstate Commerce Commission. The Federal Railroad Administration (FRA), as well as states and localities, regulates speeds and other safety-related matters; and the Railway Labor Act governs certain aspects of labor relations. There are, in addition, state and federal statutes of general applicability, such as environmental laws, that will impose a variety of constraints on the System. Various types of planning, including efforts to change existing law where necessary, may greatly reduce the burdens imposed by existing regulations. As a rule, the relevant regulations are aimed at specified activities, not particular entities, and cannot be avoided by simply employing one type of management or ownership structure rather than another. Some of these regulatory issues are discussed below.

13.4.1 Pennsylvania Public Utility Commission

Prior to June 13, 1983, if the system were operated as a wholly private venture it would have been considered a public utility subject to tariff regulation by the Pennsylvania Public Utility Commission (PUC). The PUC no longer has authority to regulate rates charged by intrastate rail carriers. Under the Staggers Rail Act of 1980, state commissions were permitted to continue to regulate intrastate rail transportation while revising their rules to conform with Interstate Commerce Commission (ICC) regulations. On March 10, 1983, the PUC informed the ICC that it would not submit revised rules or seek final certification to regulate intrastate rail rates. Accordingly, the Interstate Commerce Commission assumed jurisdiction over intrastate rail transportation in Pennsylvania.

The PUC has extensive authority to regulate grade crossings and has broad authority to insure the "adequate, efficient, and safe..." operation of all public utilities within the state.[6] The PUC has authority to issue regulations and could probably require certification of a carrier. The PUC performs rail safety inspections jointly with FRA. The two agencies must be satisfied that a proposed HSR system will be safe.

13.4.2 Interstate Commerce Commission

The ICC has authority to regulate construction, acquisition and operation of railroad lines. Applications under 49 U.S.C. 10901 for a certificate of public convenience and necessity, authorizing the construction, acquisition or operation of a railroad line, are governed by 49 C.F.R. 1150 (Certificate to Construct, Acquire, or Operate Railroad Lines). The Commission may, however, grant an exemption (under 49 U.S.C. 10504(b)) if the service is provided by a local public body and the fares charged by that body, and the authority of that body to apply to the ICC for changes in those fares, is subject to the approval or disapproval of the chief executive officer of the state in which the transportation is provided.

The term "local public body" includes not only municipalities and other political subdivisions of the Commonwealth, and public agencies, public corporations, boards, and commissions established under the law of the Commonwealth, but also "a person or entity that contracts with the local public body to provide transportation services." Presumably both private and public operating entities could, therefore, qualify for exemption.

United States Research Laboratories, Inc. (USRL), a Maryland corporation that intends to operate rail service between Los Angeles and Las Vegas, is the only rail line to have applied for exemption under the 10504(b) provision, which has been in effect only since January 12, 1983. Although USRL's application was rejected for failure to supply sufficiently detailed information, there is no indication that the ICC intends to read the exemption narrowly and attempt to retain jurisdiction over rail rates.

13.4.3 Environmental Laws

The impact of the environmental laws, both state and federal, will be felt largely during the construction phase of the project. At least potentially, a wide range of statutes is involved, including the Clean Air Act, the Federal Water Pollution Control Act, the Resource Conservation and Recovery Act, and the Rivers and Harbors Act (see Chapter 15). If there is major federal support or if federal permits are involved, it will be necessary to engage in environmental impact analysis. Such analysis will be time-consuming and costly. While Pennsylvania law does not require an environmental impact statement, the system will need to comply with a series of environmental protection statutes. In addition, Article I, Section 27, of the Pennsylvania constitution guarantees the protection of the environment. These statutory and constitutional provisions could prove fertile ground for litigation by those opposed to HSR.

13.4.4 Labor Laws

The railroad industry has had a strong union tradition, which is reflected both in current collective bargaining agreements between operating railroads and their representative unions, and in such federal protective legislation as The Railway Labor Act. The Brotherhood of Locomotive Engineers, the Railway Labor Executives' Association and the United Transportation Union demonstrated their interest in this tradition by their opposition to USRL's application for an ICC exemption. If the developing and operating entities enlist the aid of these groups, beginning early in the project, it may well be possible to design wage rates and work rules that will afford the system viability.

13.5 INTERACTION WITH THE COMMONWEALTH

In general, the range of financial returns projected for Alternatives C, D, and E are insufficient, in and of themselves, to attract private equity capital for the bulk of system financing. Separate from the problem of the level of the return is its timing.

As discussed in this chapter and in Chapter 12, positive returns to the equity investor, while projected to be substantial in the later years of the study period, do not begin until more than one-third of the 38-year period has elapsed.[7] The combination of the level and the timing of project returns suggests that the Commonwealth will need to play an important role in the implementation of the system.

The financing package discussed in Chapter 12 assumes that the Commonwealth would play a significant role in the financing of the system through its provision of a loan (or a suitable loan guarantee) for approximately 18 percent of the system's cost, on terms favorable to the HSR enterprise. While this specific mechanism is helpful in improving the level of project return, it does not substantially alter its timing. It is not clear that equity investors (or project developers) would risk their capital under these circumstances.

An alternate approach would entail the Commonwealth taking a larger role in project development through the provision of a construction loan (or loan guarantee) of 50 to 75 percent of the project, with the balance in supplier financing. At the commencement of operations, a refunding could take place through which equity capital would replace a majority of the Commonwealth's interest. Equity investors would begin to receive tax benefits immediately under this approach, and would benefit from projected positive net income at an earlier horizon (approximately the eighth operating year). This approach would appear to be more attractive from the standpoint of attracting equity capital.

In either event, the Commonwealth's role in the implementation of Pennsylvania HSR would be major. As the feasibility study continues through Phases 2 and 3, more specific financing packages will be developed, requiring further information from numerous agencies of the Commonwealth. The collective benefits to all Pennsylvanians, notably the economic impacts discussed in the next chapter, must be evaluated fully from the viewpoint of public policy.

There is substantial precedent for the Commonwealth assuming the pivotal role which may be required for HSR implementation. In another era, the early canal system of the state was developed with state funds and operated as a division of state government. When railroads came on the scene, the Commonwealth funded their development to replace certain links in the canal system while continuing to operate and improve the inclines. (In 1857, the entire state-owned "Main Line of Public Works" was sold to the Pennsylvania Railroad.)[8,9] In more recent times, the state sponsored the first limited-access superhighway, the Pennsylvania Turnpike.

13.6 CONCLUSION

Until there is greater certainty about the possibilities for raising public and private capital to construct and operate the system, it is not possible to say with assurance what the optimal institutional scenario is. Based on this preliminary exploration of possible institutional scenarios, however, it appears that, recognizing that each stage in the project has peculiar features affecting financing and taxes, the system ought to be structured to evolve in stages from public to public-private ownership and control. The principal challenge will be to manage the evolution of ownership and control so that the special tax and financing advantages associated with each of the organizational forms is optimized.

A major area of importance and uncertainty is the tax laws, which will have a major impact on financing. It may be desirable to seek legislative modifications or clarifications to ensure that tax benefits can be optimized. In addition, care should be taken to ensure that expenses are not unnecessarily increased by licensing fees or regulatory controls.

The organizational and tax issues will be addressed in greater detail during Phase 3, for the selected alternative system. The organizations discussed in this chapter should be kept informed of the status of the HSR study in Pennsylvania, and more definitive information should be developed beginning in Phase 2.

References

[1] 55 Pa. Stat. Ann. 651 et seq.

[2] 45 U.S.C. 561(c).

[3] 45 U.S.C. 655.

[4] Section 2.1 of the April 1, 1976 Off-Corridor Operating Agreement.

[5] Recently, Amtrak agreed to allow the Colorado Midland Railways to provide rail passenger service in Wyoming in return for the payment of an annual fee of $3,000, to be adjusted each year in accordance with the Consumer Price Index, and a percentage of gross revenues above break-even, rising from one percent to five percent with the increased profitability of the line. However, after intervention by U.S. Senator Malcolm Wallop of Wyoming, Amtrak agreed to accept a nominal fee of one dollar per year and no participation in the earnings of Colorado Midland.

[6] 66 Pa. C.S.A. 1501

[7] For the Alternative C, high-demand financing package discussed in Chapter 12, the operating returns on equity range from approximately -50% in the first year of operations to over 400% for the last year of the study period. The first year for which positive earnings are shown is the 16th year after investment.

[8] Burgess and Kennedy, The Pennsylvania Railroad Company, 1846-1946, Pennsylvania Railroad Co., Philadelphia, 1949.

[9] Julius Rubin, "Canal or Railroad ?," Transactions, American Philosophical Society, Vol. 51, Part 7, Philadelphia, 1961.

CHAPTER 14
ECONOMIC IMPACTS

14.1 INTRODUCTION

14.1.1 Background

A critical question in an assessment of HSR in Pennsylvania is: What contribution would the project make to economic development and urban area revitalization? This question is particularly relevant in Pennsylvania. As stated by the State Planning Board in its strategic planning document for economic development, Choices for Pennsylvanians:

> "In Pennsylvania, the lack of sufficient jobs is one of the most severe problems facing us today. During the last 10 years, the Commonwealth has lost 190,300 manufacturing jobs. In 1980, there were 417,000 Pennsylvanians out of work, nearly double the 218,000 workers who were unemployed in 1970. Our unemployment rate for 1980 (7.8 percent) was 10 percent higher than the national average (7.1 percent). Between 1970 and 1980, an estimated 435,600 Pennsylvanians moved to other states, many because there were no jobs for them in our Commonwealth.
>
> Hardest hit have been the cities and towns that once relied on factory and service workers for support of their economic base. Fewer people with fewer dollars has meant less business for the retail establishments and less municipal revenue for the communities of Pennsylvania."[1]

The Board further noted that a projection of recent trends, while revealing a growth in employment and a decline in unemployment, will fall considerably short of meeting the goals of expanded job opportunities and a healthy economy. Under the present trend forecast, there would be fewer manufacturing jobs by 1990; unemployment rates, while lower than today, would remain at unacceptably high levels; and many communities would be facing many of the same problems they are experiencing today.[2]

Clearly, the nature and magnitude of the economic effects of HSR will be major considerations as state and local officials and potential private investors determine whether the substantial investment needed to construct and operate the service is warranted.

14.1.2 Economic Impacts Analysis

Because of the significance of HSR project economic impacts, a preliminary assessment of these impacts was added to the Phase 1 feasibility study. This chapter presents the methodology and results of this analysis.

High-speed intercity rail passenger service would contribute to economic growth in several ways. First, direct expenditures associated with constructing and maintaining the service would generate employment and income for Pennsylvania residents. These direct effects would further stimulate economic growth through the "multiplier effect" as successive rounds of spending occur within the economy. HSR also may cause changes that could enhance Pennsylvania's competitive status in the regional economy ("structural" changes) and thus stimulate economic growth. For example, Pennsylvania's tourism market may be strengthened and extended beyond its current boundaries because of the improved accessibility provided by HSR service. In fact, HSR service may be a tourist attraction in its own right. In the rail supply and rail freight service industries, and industry in general, HSR service may result in both an increase in the attractiveness of doing business in the state, and an increased competitive advantage to a Pennsylvania business location. Other potential economic benefits include growth in state and local government revenues, possible reductions in public costs for transportation (e.g., highway construction and maintenance), and other public benefits such as increased transportation safety, energy conservation and use of domestic fuel sources.

14.1.3 Objective and Scope

The objective of this analysis is to establish an order-of-magnitude estimate of the range of economic impacts likely to be associated with HSR service implementation. Following selection of a preferred alternative, a more exhaustive economic impact analysis will be undertaken in Phase 3 of the feasibility study.

In this chapter, estimates of the direct impacts (from construction and from operations and maintenance) and their associated multiplier effects are presented for each of the alternatives. Quantitative estimates of travel demand and state government revenue impacts also are presented. Other indirect and induced economic impacts on tourism, rail supply, rail freight, coal and other industries will be examined later in the study.

The economic impacts are presented from two perspectives. First, statewide economic impacts are discussed in terms of the contribution which HSR service may make to gross state product, employment and personal income. Second, the distribution of economic impacts among urban areas proposed to be served by HSR is discussed. For this analysis, urban areas are defined by their Standard Metropolitan Statistical Area (SMSA) boundaries. The preliminary implications of HSR service for downtown revitalization are discussed in broad terms, and will be fully investigated and quantified later in the study.

Due to the preliminary nature of current engineering, cost, service, ridership projection and other data, the economic impact analysis reported here is incomplete and represents only a rough approximation of the nature and magnitude of impacts. For example, structural changes that could result from HSR service are not addressed quantitatively. Similarly, detailed analyses to determine net impacts, taking into account adverse effects in other parts of the economy, such as competing modes of transportation, are not included in this analysis, but will be studied during Phase 3.

The following sections present a description of the methodology used to develop the impact estimates; the estimates of statewide economic impacts; and, finally, estimates of the urban area impact. In each section, construction period impacts and operating period impacts are presented separately.

14.2 HSR ECONOMIC IMPACTS ESTIMATION METHODOLOGY

The methodology used to develop the Phase 1 economic impact estimates consists of eight basic steps. The steps and their interrelationships are shown in Figure 14-1. The basic concept of the methodology is first to estimate changes in final demand for Pennsylvania goods and services and then to trace these changes through successive rounds of expenditure in the economic system (direct, indirect, and induced) to derive the total economic impact estimates. A detailed explanation of this methodology follows.

As noted above, changes in final demand for Pennsylvania goods and services will derive from two principal sources: (1) expenditures made to construct and to operate HSR service, and (2) structural changes in the economy attributable to the existence and use of HSR service. Possible adverse economic effects such as reduced demand for alternative modes of transportation were not taken into account in this analysis.

Excluding structural changes, the change in final demand is a function of construction and O&M expenditures and the proportion of those expenditures that would be made in Pennsylvania. Construction and O&M expenditures were developed from the engineering analyses discussed in Chapter 8.

To determine the portion of these expenditures that would occur in Pennsylvania, the costs were separated into components associated with fairly discrete activities and industries. The components selected were earthwork, structures, track materials, communications and signaling, electrification, stations and maintenance facilities, right-of-way, rolling stock, and project management. A probability that expenditures for each cost component would be made in Pennsylvania was then estimated. These probabilities are based on an understanding of Pennsylvania industries, their competitors, and current supply patterns for the same or similar goods and services. The component probabilities are shown in Figure 14-2. For example, the probability that expenditures for earthwork and structures construction would be made in Pennsylvania is based on the geographic distribution of contractors who are engaged in heavy construction projects for PennDOT, the Port Authority of Allegheny County and SEPTA; the geographic distribution of heavy construction employment within the state; and traditional labor hiring practices in the heavy construction industry. (These same data were used to allocate changes in final demand among urban areas within the state, Step 6 in the methodology.) The probability of making the expenditures in Pennsylvania multiplied by the amount of expenditures provides the estimated amount of change in final demand for Pennsylvania goods and services.

The other source of change in final demand is structural economic change, which results in an increase in demand for Pennsylvania goods and services or an increase in real income accruing to Pennsylvania residents. Examples of potential structural changes from HSR service are given in the following section. For the Phase 1 economic impact analysis, only the change in travel-related expenditures was estimated. Estimates of total ridership (as reported in Chapter 9), and data on current travel patterns in Pennsylvania were used to estimate the percentage of riders who would be from out-of-state and therefore could create new final demand for Pennsylvania goods and services.[3,4] It was assumed that 20 percent of these riders would not travel to Pennsylvania without HSR service. The same data sources provided estimates of expenditures made by travelers while in Pennsylvania and the geographic distribution of

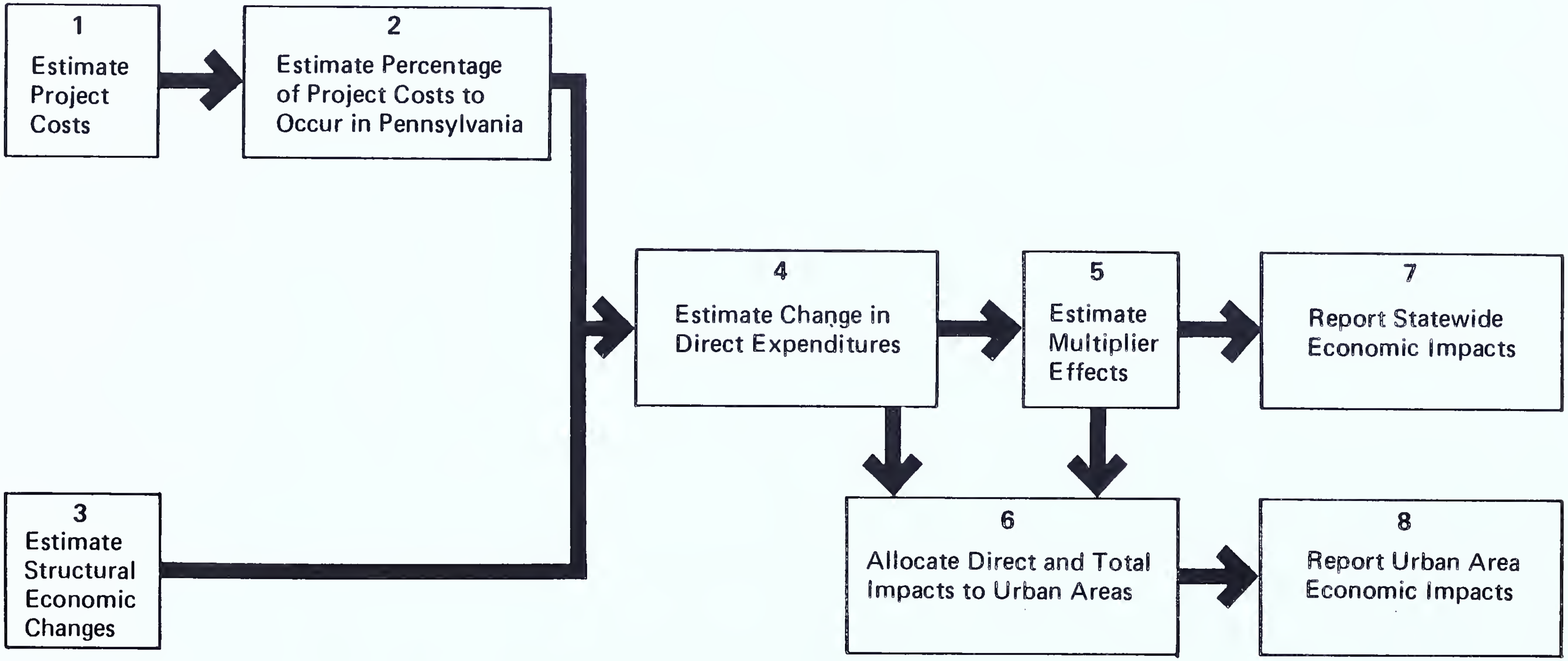

1
Estimate Project Costs
2
Estimate Percentage of Project Costs to Occur in Pennsylvania
3
Estimate Structural Economic Changes
4
Estimate Change in Direct Expenditures
5
Estimate Multiplier Effects
6
Allocate Direct and Total Impacts to Urban Areas
7
Report Statewide Economic Impacts
8
Report Urban Area Economic Impacts

Figure 14-1
Methodology for Estimating Economic Impacts from HSR Service

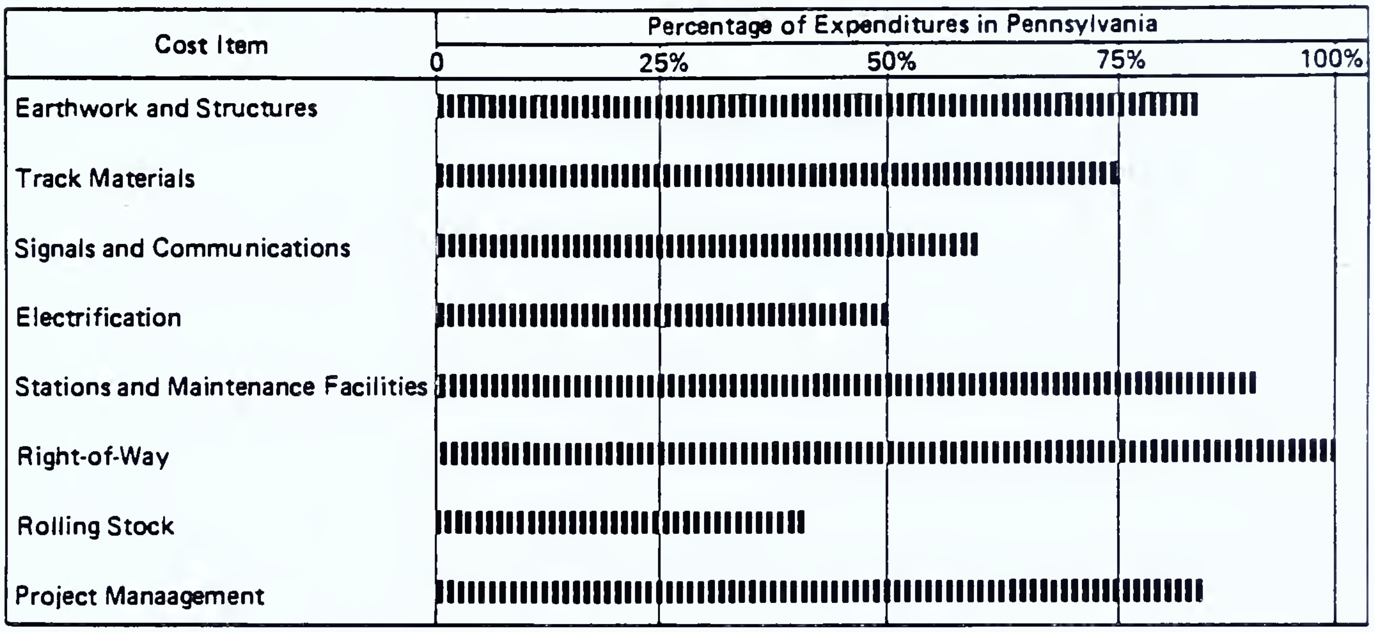


Figure 14-2
Pennsylvania's Estimated Share of Construction Expenditures

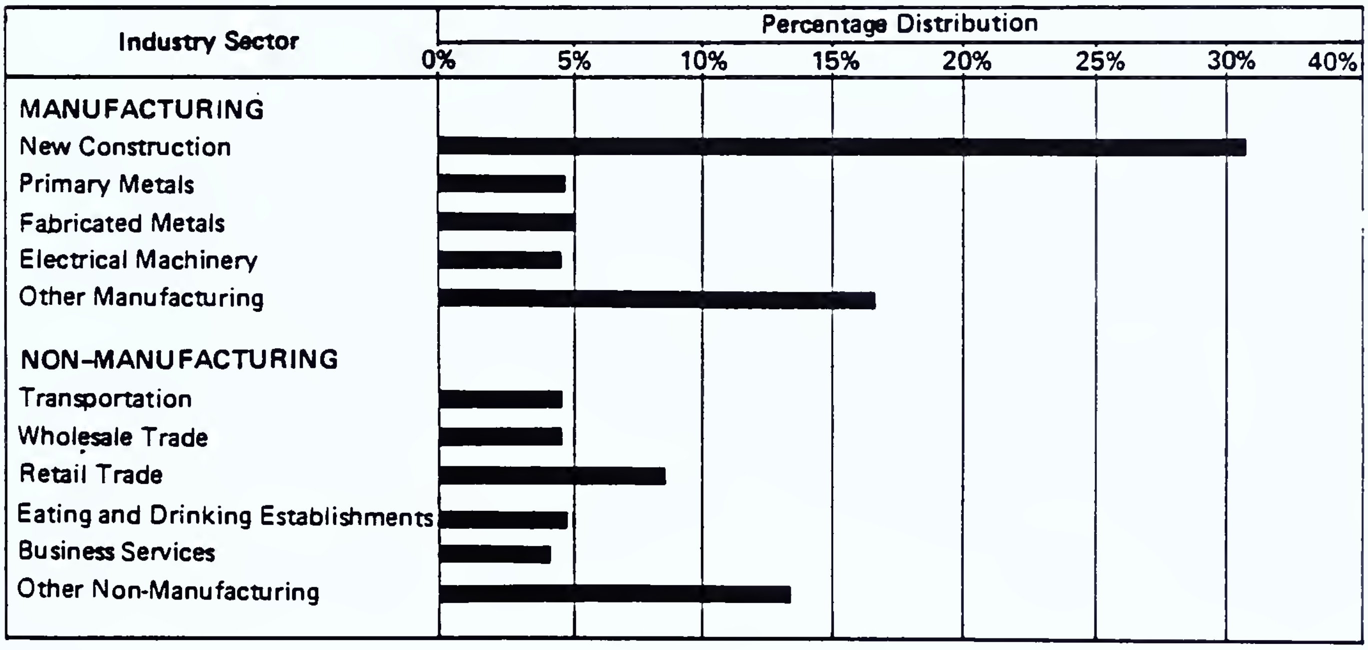


Figure 14-3
Distribution of Construction Period Impacts by Industry Sector Alternative C

these expenditures. Travel-related changes in final demand were combined with operations expenditures made in Pennsylvania to derive the total estimated annual change in final demand during the operating period.

The next two steps in the methodology are to translate changes in final demand into direct expenditures by industry sector (Step 3) and subsequently into total expenditures by industry sector (Step 4). Impacts on gross state product, personal income and employment (in person-years) are derived from changes in direct and total expenditures by using industry-specific ratios (e.g., earnings-to-expenditures and employment-to-earnings ratios).

To translate changes in final demand into direct and total expenditures, the Regional Input-Output Modeling System (RIMS II) was used.[5] RIMS II was developed by the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce. The RIMS II procedure produces estimates of regional industrial relationships (the input and output structure for each of 491 industry sectors) based on the BEA national input-output table. At our request, the BEA developed industry input-output estimates that reflect industrial relationships in Pennsylvania. The translation from the national model to the regional model is accomplished in a three-step process:

1. The national direct requirement coefficients matrix is made region-specific by using corresponding four-digit Standard Industrial Classification (SIC) location quotients.
2. Direct household earnings coefficients are based on value-added gross output ratios from the national tasks and introduced into each industry's coefficient column.
3. The total multipliers associated with each industry sector are computed using the Leontief inversion method.

The output of this process is a set of direct coefficients and total multipliers for computing effects associated with each of 491 RIMS II industry sectors. By applying the direct coefficients and the total multipliers to a change in final demand for the goods or services produced by each industry sector, the direct and total effects of that change by industry sector and for the entire regional economy can be calculated (Step 5).

The major advantage of using a RIMS II regional model is the level of detail obtained by having direct coefficients and total multipliers for each of 491 sectors. By distinguishing industries at this level of detail, one can produce a more accurate estimate of economic impacts associated with changes in final demand in specific sectors. At the same time, the RIMS II model has certain constraints common to input-output models, which must be understood in interpreting results. First, RIMS II is a static model. It can estimate the overall changes in economic activity that are likely to occur, but not the timing of the changes. Second, linear production functions are assumed, which means that long-run changes in production processes and consumption patterns will not be reflected in the coefficients and multipliers. BEA updates the database periodically to reflect these kinds of changes. Finally, government and investment spending are treated as exogenous in a RIMS II model. Thus, the model does not reflect the feedback effects on government spending induced by other changes in the economy.

The final step in the methodology prior to reporting (Step 6) was to allocate statewide impacts among urban and other areas. This was done by distinguishing direct and indirect plus induced effects. Direct effects were allocated among substate areas according to the procedures and data used to distinguish state versus out-of-state changes in final demand described above. Indirect plus induced effects were allocated in the same proportion as direct effects for those industry sectors that tend to have a local market orientation (e.g., eating and drinking establishments). Indirect and induced effects associated with industries oriented to larger market areas were allocated according to the current statewide geographic distribution of economic activity within those industries. One limitation of this approach is that possible redistribution of economic activity among substate areas is not considered. Some redistribution will be reflected in ridership characteristics and can be taken into account when ridership data by actual origin and destination are developed.

14.3 STATEWIDE ECONOMIC IMPACTS

14.3.1 Construction Period

The differences among the alternatives, in terms of construction period economic impacts, are summarized in Table 14-1. The following section discusses the range of economic impacts represented by the alternatives and the implications of the impacts on economic development. In the following discussion, the low end of the impact range reflects the economic impacts associated with Alternative C, while the high end of the range reflects Alternative E. In general terms, impacts associated with Alternative C-Electric are approximately 15 percent greater than those estimated for Alternative C. Impacts estimated for Alternative D are about four times those of Alternative C, and Alternative E impacts are about five times those of Alternative C.

The estimated capital costs for the alternatives range from $2.5 billion to $9.6 billion, based on the target cost estimates. Preliminary analyses of these alternatives and the capabilities of Pennsylvania industries indicate that Pennsylania firms and individuals may capture about 70 percent of the direct expenditures made for constructing an HSR system. The potential capture rate varies by type of expenditure as shown in Figure 14-2. This means that Pennsylvania industries could experience a direct increase of $1.3 billion to $6.6 billion in expenditures for their goods and services depending on the alternative implemented. The increase in demand would accrue predominantly to construction labor (37 percent) and the rail supply and associated industries (primary metals--17 percent; fabricated metals--17 percent; electrical machinery--7 percent). Direct employment associated with construction may range from 25,000 to 93,000 jobs, and direct earnings may range from $600 million to $1.9 billion.

Total impacts on the Commonwealth attributable to the construction period would be about three times the direct impacts and would include:

- total expenditures for goods and services of $3.9 to $22.7 billion
- a contribution to gross state product of $1.2 to $6.1 billion
- an increase in total personal income of $1.0 to $5.2 billion
- an increase in total employment of 58,000 to 292,000 person-years.

TABLE 14-1

STATEWIDE CONSTRUCTION PERIOD IMPACTS BY ALTERNATIVE

Economic Indicator	Alternative C	Alternative C-Electric	Alternative D	Alternative E
Capital Cost, millions	$ 1,845	$ 2,204	$ 7,169	$10,024
Number of Construction Years	8	8	10	12
Peak Year Expenditures	23%	23%	17%	11%
Pennsylvania Capture Rate	71%	70%	72%	66%
Employment Impact				
Direct, person-years	18,000	22,000	75,000	97,000
Total, person-years	58,000	67,000	232,000	292,000
Percent Increase in Pennsylvania Growth Rate	20%	24%	64%	68%
Personal Income				
Direct, millions	$ 400	$ 500	$ 1,500	$ 2,000
Total, millions	$ 1,000	$ 1,200	$ 4,100	$ 5,200
Percent Increase in Pennsylvania Growth Rate	4%	5%	14%	15%
Gross State Product, millions	$ 1,200	$ 1,400	$ 4,900	$ 6,100
Percent Increase in Pennsylvania Growth Rate	4%	5%	14%	15%
State Tax Revenues, millions	$ 95	$ 110	$ 385	$ 490
Percent Increase in Pennsylvania Growth Rate	9%	10%	30%	31%

The distribution of these impacts among major industry sectors is shown in Figure 14-3 for Alternative C. The predominant benefits will accrue to the construction industry (railroad, structures and facilities construction). Significant shares also will accrue to rail supply industries (for rail and rail fastenings, rolling stock and electrification materials). Significant spin-off effects will occur in the non-manufacturing sectors, particularly transportation, wholesale and retail trade, business services and others.

Alternatives C-Electric and D have impact distributions similar to that of Alternative C. Alternative E has a substantially higher electrical machinery component as shown in Table 14-2, which compares the impact distributions of Alternatives C and E.

The estimated construction period economic benefits would be dispersed over the 8- to 12-year construction period. At the peak of construction, the annual economic impacts would be between 12 and 23 percent of the total, depending on the alternative selected.

Compared to the current level of economic activity in Pennsylvania, these impacts are small. The addition to gross state product (based on 1980 figures) would be less than 2 percent on an annual average basis. Similar contributions to earnings (personal income) and employment are projected.

At the same time, the economic impacts of HSR service are by no means inconsequential. Baseline economic projections (i.e., without inclusion of HSR impacts) prepared for the Commonwealth for the 1980-1990 period indicate annual average rates of growth in gross state product (2.7 percent), personal income (2.5 percent), and employment (0.8 percent).[6] This analysis assumes that these projections hold true throughout the implementation of the project. HSR implementation would have the following construction period impacts:

- an increase in the gross state product growth rate of from 4 percent to 15 percent
- an increase in the personal income growth rate of from 4 percent to 15 percent
- an increase in the employment growth rate of from 20 percent to 68 percent.

For example, the baseline projection for employment growth is about 36,000 jobs annually, on average.[7] During the construction period, the HSR service would add to this rate between 7,600 jobs (Alternative C) and 24,000 jobs (Alternative E) annually, on average. This represents a 20 percent to 68 percent increase in the baseline annual growth rate during the construction period. These effects of HSR are shown graphically in Figures 14-4 and 14-5 for Alternatives C and E, respectively.

14.3.2 Operating Period

During the operating period, economic impacts would derive from three sources: (1) operation and maintenance of the HSR service, (2) travel-related expenditures, and (3) structural economic changes associated with HSR service. The differences in impact between Alternatives C and E are summarized in Table 14-2. In the following section, the range of operating period economic impacts represented by the alternatives is discussed. Reference is made to the significance of the impacts with respect to economic growth in the state. The low end of the range reflects the impacts of

TABLE 14-2

CONSTRUCTION PERIOD IMPACTS BY INDUSTRY SECTOR

Industry Sector	Alternative C	Alternative E
Manufacturing		
New Construction	29.5%	25.1%
Primary Metals	4.8	4.9
Fabricated Metals	5.0	4.4
Electrical Machinery	4.7	11.8
Other Manufacturing	16.4	13.2
Non-Manufacturing		
Transportation	4.6	4.5
Wholesale Trade	4.6	4.6
Retail Trade	8.4	8.4
Eating and Drinking Establishments	4.8	5.0
Business Services	4.1	3.9
Other Non-Manufacturing	13.1	14.2
	100%	100%

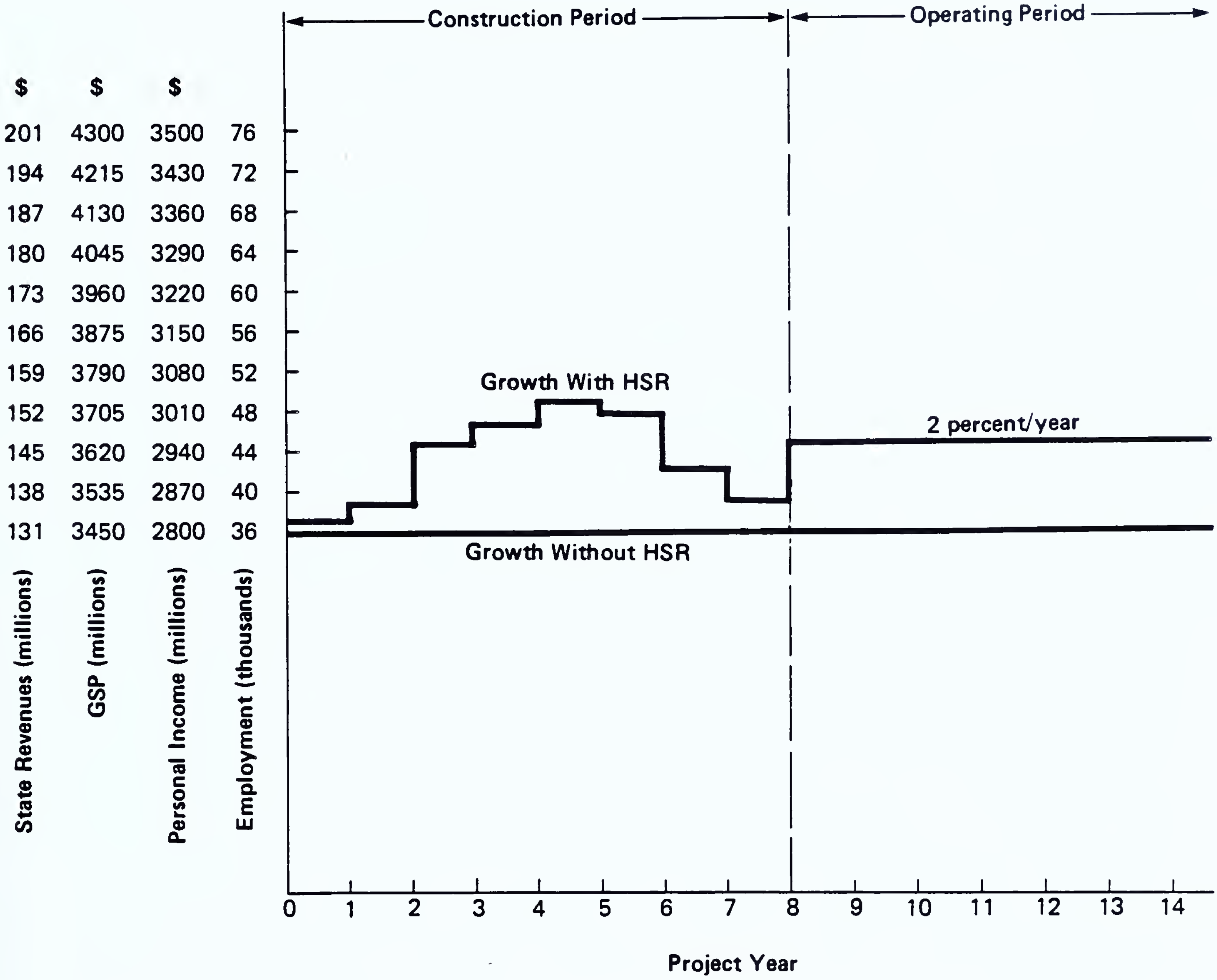


Figure 14-4

Impact of HSR on Economic Growth Alternative C—Base Demand

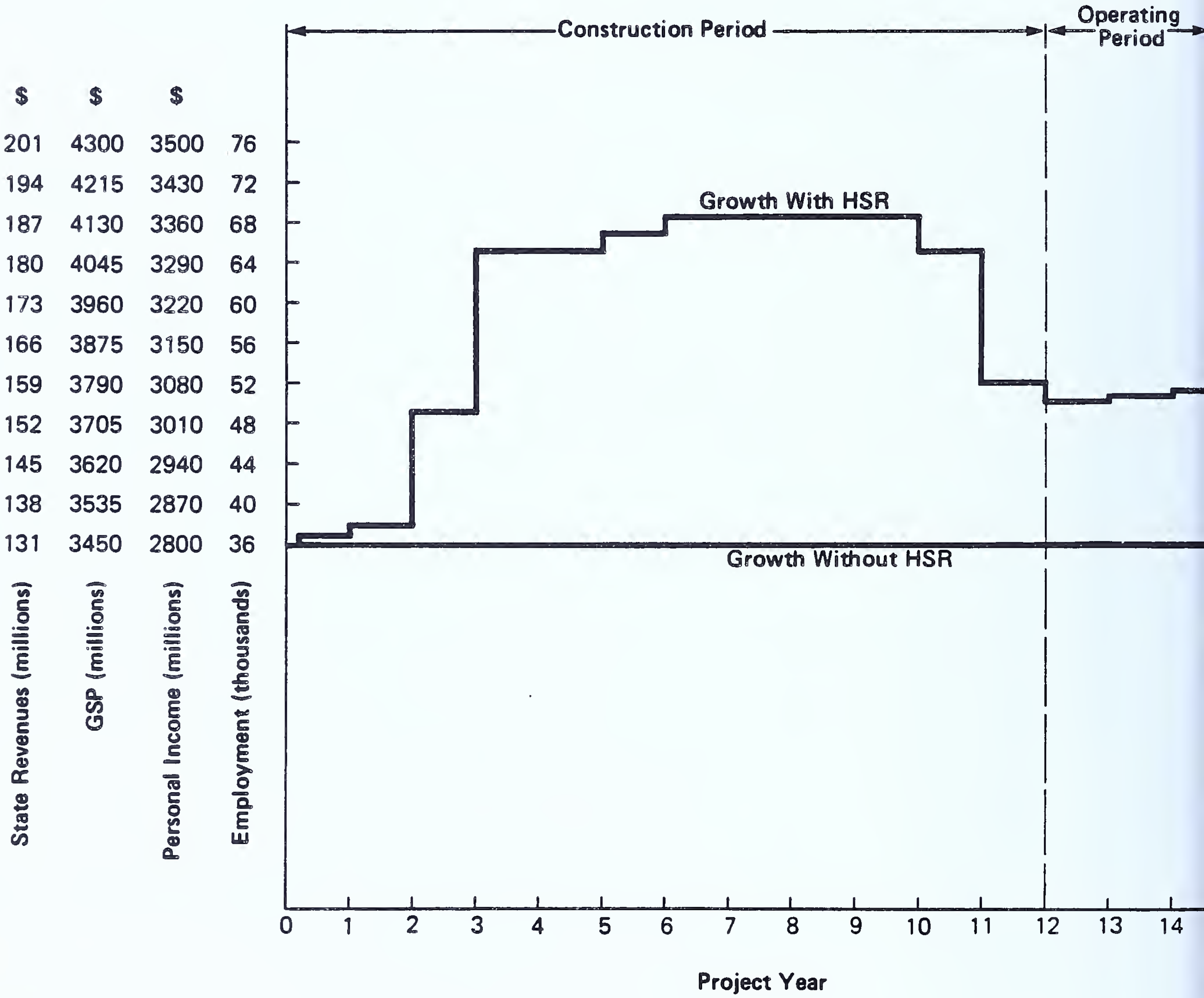


Figure 14-5
Impact of HSR on Economic Growth Alternative E—Base Demand

Alternative C; the high end of the range reflects the impacts of Alternative E. As shown in Table 14-3, the economic impacts associated with the other alternatives (C-Electric and D) fall within this range.

The operating period impacts presented below reflect the base-demand scenario in the year 2000. The high-demand scenario would result in a 50 percent greater employment effect and a 40 percent greater effect on personal income and gross state product, for Alternative C. These increases would be 40 percent and 30 percent, respectively, for Alternative E.

Direct Operation and Maintenance Impacts

The estimated impact of operating and maintaining the HSR service, like the construction period impact, is small relative to total economic activity, but is significant in its contribution to economic growth rates. The estimated cost for operating and maintaining the system ranges from $108 million for Alternative C to $166 million for Alternative E, for the base-demand levels. It is estimated that Pennsylvania would capture about 85 percent of the expenditures made for operations and maintenance. This would result in a $92 million to $141 million increase in direct expenditures for Pennsylvania goods and services, depending on the alternative implemented. Direct earnings associated with these expenditures are expected to range from $75 million to $113 million, and direct employment is expected to range from 3700 jobs to 5700 jobs. The primary beneficiaries would be railroad labor (56 percent), railroad suppliers (18 percent), and electric utilities (26 percent).

Direct Travel-Related Expenditures Impacts

Travelers who use the HSR service will spend money for food, lodging, local transportation, entertainment and incidentals. To the degree that these are new expenditures, they would represent an additional economic impact of HSR service. Initial rough estimates of this impact have been developed. If travel characteristics of HSR service patrons are similar to those of the general Pennsylvania intercity traveler, 56 percent of all HSR passengers will be residents of other states and each passenger will spend $90 per trip excluding rail service costs.[8,9] It is further assumed that 20 percent of these out-of-the-state riders would not have traveled to Pennsylvania without HSR service. Given these assumptions and base-demand ridership estimates, HSR service would generate direct expenditures of between $23 million and $33 million annually in travel-related Pennsylvania industries depending on the alternative implemented, for the year 2000. Direct earnings associated with these expenditures are expected to range from $10 million to $12 million, and direct employment is expected to range between 800 and 1,100 jobs.

Because these estimates are based on assumptions rather than market data, they represent only rough indicators of what could occur. A more detailed assessment of these impacts will be conducted later in the feasibility study.

Structural Economic Changes

In addition to impacts stemming from operation and maintenance of HSR service and from travel-related expenditures are changes that could enhance Pennsylvania's competitive status in the regional and national economies. Examples of these types of potential "structural" changes are the following:

TABLE 14-3

STATEWIDE OPERATING PERIOD IMPACTS BY ALTERNATIVE
Base Demand, Year 2000

Economic Indicator	Alternative C	Alternative C-Electric	Alternative D	Alternative E
Annual O&M Cost, millions	$ 108	$ 105	$ 124	$ 166
Annual Ridership, millions	4.2	4.2	5.1	5.9
Employment Impact				
Direct, permanent jobs	4,500	4,400	5,300	6,800
Total, permanent jobs	8,300	8,100	9,600	12,500
Percent Increase in Pennsylvania Growth Rate	23%	23%	27%	35%
Personal Income				
Direct, millions	$ 85	$ 85	$ 100	$ 125
Total, millions	$ 140	$ 140	$ 160	$ 205
Percent Increase in Pennsylvania Growth Rate	5%	5%	5%	7%
Gross State Product, millions	$ 165	$ 160	$ 190	$ 245
Percent Increase in Pennsylvania Growth Rate	5%	5%	5%	7%
State Tax Revenues, millions	$ 13	$ 13	$ 15	$ 19
Percent Increase in Pennsylvania Growth Rate	10%	10%	11%	15%

- The HSR system may induce investment in HSR technology in Pennsylvania, placing the state in an excellent position to capture a substantial portion of this potential market. In particular, the development of a trained labor force and an HSR supply industrial base could place Pennsylvania firms in the forefront of this market.

- Insofar as a common right-of-way is shared with rail freight lines, an opportunity may exist to share advanced technology and costs resulting in more efficient operations for rail freight as well as HSR services.

- The transportation improvements provided by HSR service, and perhaps the rail freight service change noted above, could enhance the competitive position of Pennsylvania industries and make Pennsylvania a more attractive place to locate new business. This would mean new investment and increased demand for Pennsylvania goods and services.

- Creation of a synergistic effect between HSR service and the tourism industry: by improving accessibility, the rail service could expand the geographic extent of the tourism market, which could in turn induce investment in new tourist attractions, further expanding the size of the market. Additionally, HSR service itself could be a tourist attraction which could increase Pennsylvania's penetration of the tourist market.

While it is clear that these impacts may be substantial, it is premature to estimate their potential magnitude. Much more detailed information concerning the HSR service characteristics and a very detailed economic analysis are required. This work will be done during Phase 3.

Total Operating Period Impacts

The combination of operating and maintenance economic impacts and travel-related-expenditure impacts provides an indication of the range of total impacts possible after operations begin. The combined impacts, including the multiplier effects, are estimated to be as follows in the year 2000:

- an increase in total expenditures for goods and services of between $300 and $460 million annually
- a contribution to the gross state product of between $165 and $245 million annually
- an increase in total personal income of between $140 and $205 million annually
- an increase in total permanent employment of between 8,300 and 12,500 jobs.

As noted earlier, these economic impacts are projected to increase over time as ridership grows by an estimated 2 percent annually; further, these impact estimates exclude other structural economic changes that would occur with operation of an HSR service.

The operating period economic impacts represent only a small addition (less than 1 percent) to current levels of economic activity in the state. However, during the first year of the operating period, the baseline growth rate in employment (36,000 jobs) would be increased by 8,300 jobs (Alternative C) to 12,500 jobs (Alternative E). This is an increase in the growth rate of between 23 percent and 35 percent. Increases in the growth rates for gross state product and personal income are 5 percent to 7 percent. These relationships are shown in Figures 14-4 and 14-5 above. The figures also indicate that the economic benefits during the operating period are expected to increase beyond the initial operating year.

It also is appropriate to note that the estimated impacts for the initial years of operation are from 50 to 115 percent of the estimated annual average construction period impacts. The significance of this finding is that high-speed rail service could create sustained benefits and would stimulate the Pennsylvania economy on a long-term basis, quite apart from the construction period impacts it would necessarily create.

14.3.3 State Government Revenues and Costs

In addition to the impacts on the economy, HSR service also would contribute to the generation of state government revenues. Applying a simple ratio of government revenues received to personal income (derived from historical data), the following estimates of annual additions to state government revenues are projected for the range of alternatives under consideration:

- during construction: between \$12 million and \$41 million
- during operation: between \$13 million and \$19 million, base-demand scenario
  (between \$18 million and \$26 million, high-demand scenario).

These estimates represent 1 percent or less of current revenues accruing to state government. With these additions, the projected annual growth rate of state government revenues would increase up to 31 percent. These additions could be used to finance part of the HSR system's construction or operation, should the Commonwealth decide to make a financial commitment to the system.

Costs to state government also may be affected. On the one hand, it is unlikely that costs would increase because the increment to total population served by state government would be quite small. (Less than 1 percent, assuming population would change in direct proportion to the change in employment impact of HSR service.) On the other hand, there are some reasons to expect a modest decline in government costs. Increases in employment and income reduce unemployment and associated public costs. Building an HSR system could reduce public expenditures for new construction and maintenance in other modes of transportation.

Also of potential public benefit is an expected reduction in the number of travel-related accidents through HSR operations. As an example, the Japanese Shinkansen system has operated for 20 years without a passenger fatality. In addition, HSR may be more energy-efficient than other modes, depending on load factors; and, if electrified, HSR service could be petroleum-independent.

14.4 URBAN AREAS ECONOMIC DEVELOPMENT IMPACTS

14.4.1 Introduction

Also of considerable importance in an economic impact analysis of HSR service is the effect on urban areas served. These areas — Altoona, Greensburg, Harrisburg, Johnstown, Lancaster, Philadelphia and Pittsburgh, and others — would experience growth in employment and personal income. Furthermore, insofar as the economic activities associated with HSR service would be concentrated around station locations, the rail service may contribute to revitalization of downtown areas. For the Phase 1 analysis of economic impacts, the urban areas are defined by their respective SMSA boundaries. Economic effects which may be experienced in Greensburg are contained with the Pittsburgh SMSA (Allegheny, Beaver, Washington and Westmoreland counties) impact estimates.

The following section discusses the range of urban area economic impacts that could follow introduction of HSR service in Pennsylvania. As in the previous sections, the low end of the range reflects Alternative C; the high end represents Alternative E.

14.4.2 Construction Period

Table 14-4 shows the estimated distribution of economic impacts among the SMSAs during the construction period by alternative. The impacts are specified in terms of potential employment benefits to each area. Expenditures and earnings impacts also would reflect this distribution. The distribution presented in the exhibit indicates that the urban areas may capture 70 percent or more of the total impact during construction.

The amount of impact on each urban area reflects that area's relative ability to capture direct expenditures as well as the multiplier effects of successive rounds of spending. As shown, the large urban areas, Philadelphia (22 percent) and Pittsburgh (28 percent), are more able than others to capture large shares of the total economic impacts. Their economies have substantially more heavy construction and railroad supply industries. They also are more self-sufficient economically and thus are better able to retain the multiplier effects within their areas.

Significantly, however, the magnitude of impact on the smaller urban areas — Altoona, Harrisburg, Johnstown and Lancaster — is equal to or more substantial than the larger areas relative to their respective economic bases. The data in Table 14-4 reveal that while the smaller areas may receive a lesser absolute share of the impacts, the benefit in terms of economic growth is up to two times greater than the amount their larger counterparts are expected to experience. While the absolute difference in impacts varies among the HSR alternatives, the relative distribution of impacts among the urban areas differs little among the alternatives.

14.4.3 Operating Period

Similar projections are obtained for the economic impacts estimated to be experienced after the system becomes operational. The employment impacts are shown

TABLE 14-4

CONSTRUCTION PERIOD IMPACTS BY URBAN AREA*
(Number of Person-Years of Employment)

Alternative	Urban Area							
	Altoona	Harrisburg	Johnstown	Lancaster	Philadelphia	Pittsburgh	Other	Total
C								
Employment Impact	1,900	5,500	1,900	3,900	12,600	16,300	15,900	58,000
Percent of Total	3%	10%	3%	7%	22%	28%	27%	100%
Contribution to Growth	0.4%	0.7%	0.2%	0.4%	0.1%	0.2%	-	-
C-Electric								
Employment Impact	2,100	6,000	2,100	4,300	14,400	19,800	18,300	67,000
Percent of Total	3%	9%	3%	6%	22%	30%	28%	100%
Contribution to Growth	0.5%	0.8%	0.3%	0.3%	0.1%	0.3%	-	-
D								
Employment Impact	6,900	22,700	6,500	15,800	57,800	66,100	62,200	232,000
Percent of Total	3%	10%	3%	7%	22%	28%	27%	100%
Contribution to Growth	1.3%	2.3%	0.6%	0.9%	0.3%	0.7%	-	-
E								
Employment Impact	7,500	18,700	7,100	19,600	66,200	83,200	89,700	292,000
Percent of Total	3%	6%	2%	7%	23%	28%	31%	100%
Contribution to Growth	1.2%	1.6%	0.5%	0.8%	0.3%	0.7%	-	-

*Contribution to growth is calculated as annual employment impact divided by 1980 urban area employment.

in Table 14-5 for the base-demand scenario. Under the high-demand scenario, the employment impacts would be between 40 and 50 percent greater. While not tabulated, the personal income impacts would be of the same order of magnitude.

The urban areas tend to capture a larger share of the total state economic impact after operations commence (about 80 percent versus 70 percent during construction). This result occurs because O&M activities are predominantly local. Also, travel-related expenditure impacts, which are included in the operating period estimates, would benefit predominantly the urban areas served by the HSR system.

As with the construction impacts, the larger urban areas are expected to experience the largest share of the economic benefits attributable to HSR service operations. However, in terms of relative contribution to economic activity, the smaller areas would experience greater gains (at least two times greater than Philadelphia and Pittsburgh). It also is important to recall that potential structural economic changes (e.g., to the rail freight, rail supply and other industries) are not included in these preliminary economic impact estimates.

The contribution to growth due to operating and maintaining the rail service and to travel-related-expenditure effects varies considerably among the urban areas. At one extreme is Philadelphia, where travel-related-expenditure impacts represent about 40 percent of the total impacts estimated for the area. At the other extreme is Altoona, where these impacts represent less than 5 percent of total estimated impacts. For the other areas, the contribution from travel ranges from 10 percent to 35 percent. Three aspects of the travel-related-expenditure estimates should be noted, however. First, the estimated statewide impacts from travel were distributed according to current travel expenditure distributions among the urban areas. Future ridership analysis will reveal the accuracy of this assumption. Second, the travel-related-expenditure impacts are based on assumptions (described in Section 14.3.2) that will not be validated until later in the study. Finally, the travel-related impacts by urban area are an allocation of statewide impacts. Thus, the analysis excludes possible redistribution of travel-related impacts among urban areas and other parts of the state. In this respect, the impacts at the urban area level may be understated.

Also significant is the pattern of growth exhibited by the economic impact estimates, as illustrated in Figure 14-6 for the case of Pittsburgh. Two observations are important regarding this trend: First, the annual operating impacts are more than 40 percent of the annual average impact during construction; Second, expectations are that the operating period impacts will grow over time along with ridership growth and perhaps other structural economic changes. The conclusion is that HSR could make a sustained and probably an increasing contribution to economic activity in the urban areas.

As with the construction period impacts, the alternatives differ in terms of absolute magnitude. The highest alternative is estimated to produce from approximately 20 percent to 115 percent greater impacts than the lowest alternative as measured by jobs, depending on the urban area. The relative distribution pattern among urban areas, however, does not vary substantially among the alternatives.

TABLE 14-5

OPERATING PERIOD IMPACTS BY URBAN AREA*
(Permanent Jobs, Year 2000)

Alternative	Urban Area							
	Altoona	Harrisburg	Johnstown	Lancaster	Philadelphia	Pittsburgh	Other	Total
C								
Employment Impact	1,200	900	500	700	1,300	2,100	1,600	8,300
Percent of Total	15%	11%	6%	8%	16%	25%	19%	100%
Contribution to Growth	2.3%	0.4%	0.5%	0.4%	0.1%	0.2%	-	-
C-Electric								
Employment Impact	1,200	900	500	700	1,300	2,100	1,400	8,100
Percent of Total	15%	11%	6%	9%	16%	26%	17%	100%
Contribution to Growth	2.3%	0.4%	0.5%	0.4%	0.1%	0.2%	-	-
D								
Employment Impact	1,300	1,100	600	800	1,500	2,400	1,900	9,600
Percent of Total	14%	11%	6%	8%	16%	25%	20%	100%
Contribution to Growth	2.5%	0.5%	0.6%	0.4%	0.1%	0.2%	-	-
E								
Employment Impact	1,800	1,300	800	1,000	2,800	2,600	2,200	12,500
Percent of Total	14%	10%	6%	8%	22%	21%	19%	100%
Contribution to Growth	3.5%	0.6%	0.8%	0.6%	0.2%	0.3%	-	-

*Contribution to growth is calculated as employment impact divided by 1980 urban area employment.

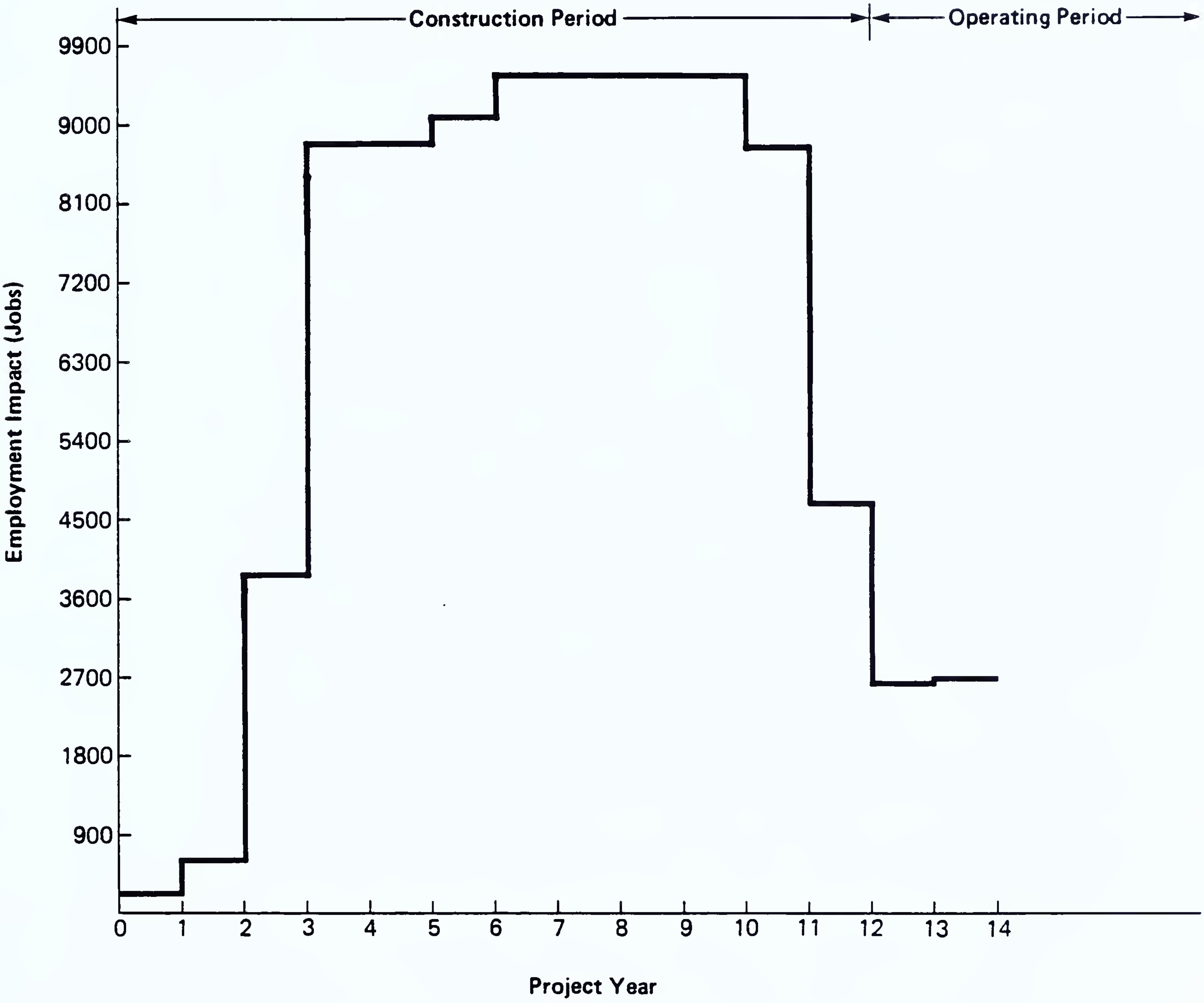


Figure 14-6

Urban Area Employment Impact
Alternative E—Base Demand, Pittsburg

14.4.4 Urban Revitalization Impacts

HSR passenger service is expected to contribute to urban revitalization. Historical experience with transportation networks and more recent experience with rail rapid transit systems show that this expectation is realistic. As noted earlier, travel-related-expenditure impacts may represent a large share of the economic impacts during the operating period and much of this activity could focus on the downtown areas around stations. Similarly, the accessibility that would be offered by HSR service may attract service types of business to locate in the vicinity of stations. Clearly, these types of new development and redistribution of existing development have occurred around airports, major highway interchanges, and many rail rapid transit system stations.

This experience has revealed important characteristics of the dynamic relationship between rail passenger service and development around stations. The basic conclusion is that HSR service can influence the location and timing of downtown development, but that such service is only one of several factors necessary to cause downtown revitalization. Paramount among these factors is the economic vitality of the area economy and the implementation of public policies which take advantage of the redevelopment opportunity through aggressive support of development around stations. Other important factors include the station locations and characteristics, trip purposes, the significance of intercity accessibility to emerging development opportunities, and the relative attractiveness of alternative locations.

Possible Development Sites

Within walking distance of each of the seven stations, sites are available for development; however, they vary greatly in quality from city to city.

Both Pittsburgh and Greensburg have, relative to their respective sizes, excellent development sites that easily could absorb any secondary investment generated by HSR operations. Altoona, Harrisburg and Lancaster also have good sites that could respond to the economic stimulus generated by HSR. Altoona and Harrisburg, especially, are in a position to capitalize upon any such opportunity. Both have experienced public agencies capable of supporting private investment; both have a successful record of inducing private investment in the physical vicinity of the station; both are aggressively seeking new opportunities in their central areas, and both have the necessary economic base in place near their stations, to support additional expansion. In these four cities (Pittsburgh, Greensburg, Altoona and Harrisburg), any secondary investment would be accommodated readily.

In two cities, Johnstown and Philadelphia, the station location and the surrounding development pattern preclude the rich assortment of possible development sites existing in the other cities. In both cities, secondary investment most likely could be accommodated within the modified station structure or in the nearby central business districts.

Corridor Cities' Growth Policies

In five cities — Pittsburgh, Greensburg, Johnstown, Altoona and Harrisburg — the stations are located in or are immediately adjacent to districts in which positive investment policies have been pursued. HSR service should be welcomed in these cities not only for the increased convenience and economy of travel, but also for any induced secondary investment or perceived economic advantage which may flow from the successful operation of the line.

In Lancaster, the station is located on the northern edge of the city about a mile from the Central Business District (CBD). Lancaster has spent a considerable amount of money over the past two decades in major revitalization efforts in its older core. These efforts are beginning to show some success. Development at the station area could be considered competitive with downtown Lancaster. In addition, some of the potential sites around the station are in Manheim Township rather than in the City of Lancaster. The city, with the cooperation of the township, could control secondary investment through favorable land use regulations, thus insuring the benefits of HSR service while avoiding what might be undesirable patterns of investment.

In Philadelphia, public policy has directed market (as opposed to institutional) growth to the east of the 30th Street Station into the CBD. In recent years, this policy has shifted the emphasis even further east to East Market Street, the Old City and even the Delaware River waterfront. It is unlikely that the City would welcome forces that would divert investment as far west as 30th Street. It is unlikely that the passenger traffic added by HSR to the level already existing at 30th Street would induce a secondary investment response. In short, if the superb accessibility patterns around 30th Street Station were going to induce an investment response, they would have done so already. HSR service is not likely to divert the existing investment patterns in Philadelphia; however, the increased convenience would add to the overall development level in the CBD.

Potential Development Impact

If a city's area-wide economy were dynamic and if public policy were designed to capitalize on the potential secondary investment opportunities offered by HSR operations, then the community could realize major development activity in the station area. Of the cities examined, three seem to have a favorable combination of a good station location, public policies favoring investment in the station vicinity and good potential development sites. These cities are Pittsburgh, Altoona, and Harrisburg. Johnstown's station is somewhat removed from prime center city locations. Nevertheless, aggressive public policy could capture some spin-off effects. Greensburg should be able to generate an adequate public policy response to support the excellent station location and the adjacent development opportunity sites. The Philadelphia and Lancaster station locations do not support current public growth policy and investment. Therefore, in these cities secondary growth benefits would probably be limited.

The primary type of secondary investment that would be triggered in downtown areas around the stations would be office development. To some extent, this would be a concentration near the station of office growth that would occur elsewhere in the region (including suburban locations) absent HSR. The construction and operation of the line will create primarily locational advantages near the stations, and this will tend to reallocate regional growth. Generally, as office growth concentrates, the aggregation tends to attract or generate additional growth. It is possible that the increased attractiveness of the downtowns in the cities served by close-in HSR stations could increase the net office growth in the region. These downtowns could become the centers of broader economic revitalization than the regional growth projections would indicate; they could bring in new investment.

To determine the potential for office development in each of the stations, office employment (including government employment in Harrisburg) was projected as a proportion of total population in the year 2000. The proportion was adjusted for changes in the economic structure that are expected to increase office employment over the remaining years of this decade. Net square footage space requirements per office employee were estimated for the year 2000, based on an assumption of the continuation of the current trend, which indicates a slowly declining increase in area per person for the next 15 years.

The total net office space required for each city was the product of total office employment times the projected area per employee. This was compared with the existing (generally 1980) inventory. A portion of the city-wide increase was then assigned to the center city area. The data necessary for these projections were unavailable for either Philadelphia or Pittsburgh and, therefore, no office growth projections for these two cities have been made. In addition, Lancaster is excluded because, as stated above, the HSR station will not greatly influence center city office location decisions.

Office growth potential to the year 2000 for center city station areas is detailed in the following table for those cities which are most susceptible to the positive impact of HSR service:

Potential Downtown Office Development
Near HSR Stations
1984-2000

City	Potential Net Square Feet of New Office Construction
Altoona	160,000 - 200,000
Greensburg	75,000 - 100,000
Harrisburg	360,000 - 400,000
Johnstown	295,000 - 340,000
Pittsburgh, Philadelphia	(data not available)

To reemphasize the point, HSR alone will not drive office investment to its potential. Only a combination of state and regional economic health (which would be fostered by HSR construction and operation), public policies supporting new investment, and HSR operations in the downtown station locations will enable this new office investment potential to be fully realized.

14.5 SUMMARY AND CONCLUSIONS

Because of the preliminary nature of available data, the economic impact analysis reported here represents only a rough approximation of the nature and magnitude of potential impacts. Nonetheless, it does present a range of basic effects that can be expected to result from HSR service in Pennsylvania.

14.5.1 State Impacts

The basic finding is that Pennsylvania industries can capture a substantial share of the direct expenditures for constructing and operating an HSR system. About 70 percent of the direct construction expenditures and 85 percent of the direct operating expenditures would accrue to Pennsylvania firms and workers. In addition, direct expenditures associated with HSR travel could be sizable. Thus, HSR service could pump $145 to $415 million of new, direct expenditures annually into the Pennsylvania economy, during construction, and $115 to $175 million annually during operations, depending on the alternative.

These direct economic effects would in turn cause multiplier effects as successive rounds of spending occur within the economy. Total economic impacts associated with HSR service would be three times the size of the direct effects.

Employment Impacts

The effect on employment in Pennsylvania would include 58,000 to 292,000 person-years of employment during the construction period for Alternatives C and E, respectively. This would mean on the order of 7,000 to 24,000 jobs on average for each year of the construction period. Significant increases in employment would continue after operations begin. By the year 2000, 8,300 permanent jobs could be created under Alternative C; 12,500 jobs could be created under Alternative E. In terms of contribution to growth in Pennsylvania employment, construction and operation of an HSR system could cause a 20 percent to 68 percent increase in the growth rate during construction years. After operations begin, the increase could range from 23 percent to 35 percent. The employment impacts for all alternatives are summarized in Figure 14-7 for both the construction and operating periods.

Gross State Product

Another indicator of economic activity is gross state product. HSR expenditures and their multiplier effects would bolster the growth rate of gross state product by 4 percent to 15 percent annually on average during the construction years. During the operating period, the contribution could be in the range of 5 percent to 7 percent for Alternatives C and E, respectively.

In dollar amounts, implementation of Alternative C would add an annual average of $150 million to the gross state product during the construction period and $165 million in year 2000 of the operating period. Under Alternative E the contribution would be $510 million annually during construction and $245 million in the year 2000.

Personal Income Impact

Jobs also mean increases in personal income for Pennsylvania residents. During the construction years, personal income could be increased by $125 million on average annually under Alternative C. This would represent an increase in the current personal income growth rate in Pennsylvania of about 4 percent. Under Alternative E,

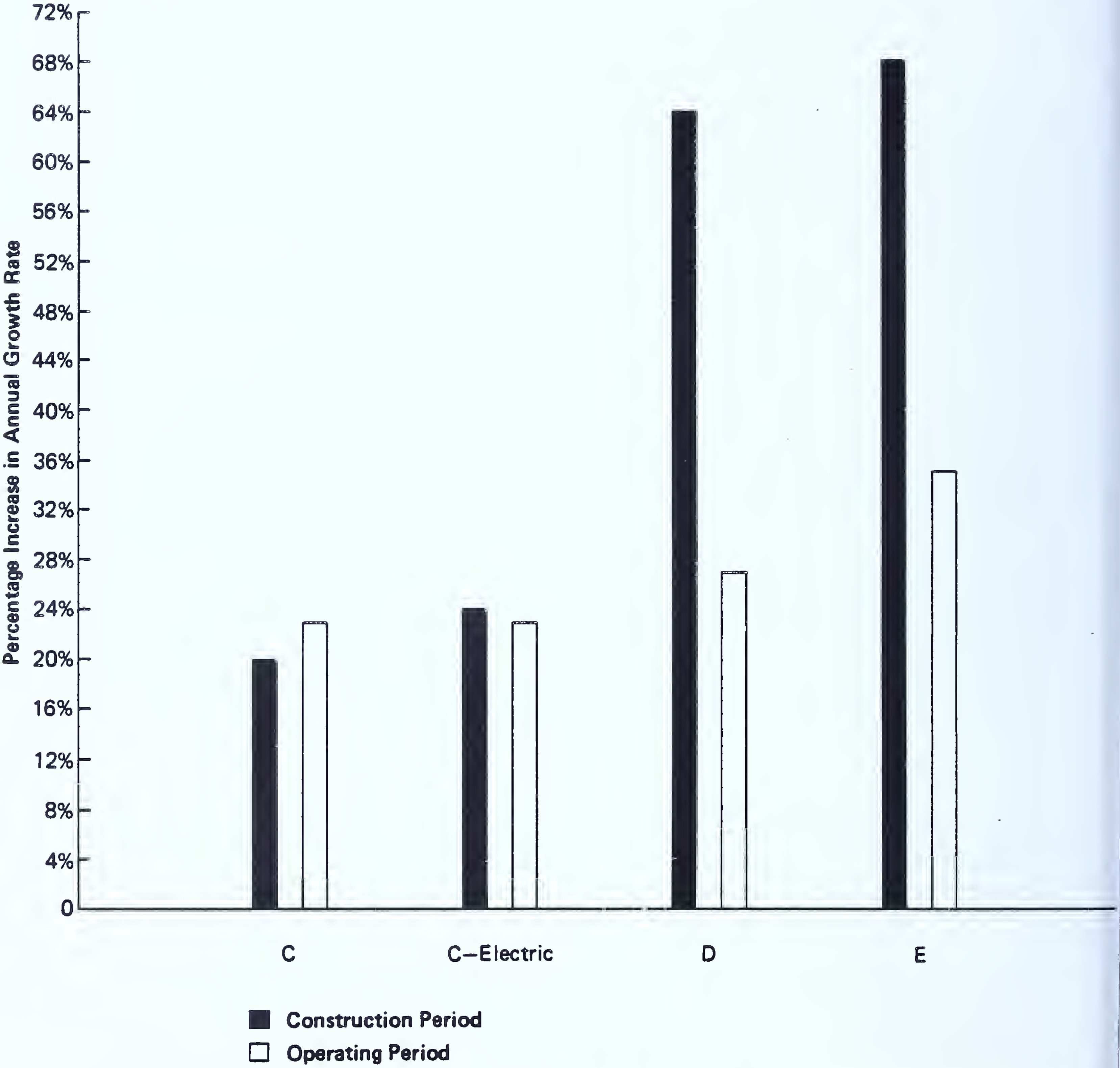


Figure 14-7

Impact of HSR on Employment Growth Rate— Base Demand

the average annual increase could be $430 million, which would increase current projected growth rates by 15 percent.

During operations, personal income effects would continue, with the contribution reaching $140 million in the year 2000 under Alternative C and $203 million under Alternative E. These figures represent an increase of 5 percent to 7 percent in the annual growth rate of personal income for state residents.

State Government Revenues

Increases in economic activity also add to the revenues accruing to state government. Based on the income projections stated above, state government revenues would increase by $12 million (Alternative C) to $41 million (Alternative E) on annual average during the construction period. After operations begin, the annual addition to state government revenues would be $13 million and $19 million, respectively, for the alternatives. The percentage increases in the growth rate of revenues would be from 9 percent to 31 percent during the construction years and 10 percent to 15 percent during the operating years.

The impacts on economic growth rates are summarized in Table 14-6 for all alternatives.

14.5.2 Urban Area Impacts

Most of the economic benefits would accrue to the urban areas proposed to be served by HSR service. These areas are projected to receive 70 percent of the construction period benefits and 80 percent of the operating period benefits. Philadelphia and Pittsburgh would receive the largest shares of the benefits — more than 20 percent each during construction and operations. However, while the smaller areas may receive a lesser absolute share of the impacts, the benefits to their economic activity in relative terms are two times or more what their larger counterparts are expected to experience.

HSR service could benefit downtown revitalization as well as the overall economic development of the urban areas. Travel-related-expenditures impacts are expected to represent a large share of the economic impacts during the operating period. Much of this activity could focus on the downtown areas around stations. Similarly, the accessibility that would be offered by HSR service may attract service types of businesses to locations in the vicinity of stations. The development is likely to include commercial, retail, office and lodging components. There also may be opportunities for specialized developments such as sports arenas and other recreational or cultural attractions. However, for HSR's potential contribution to downtown revitalization to be realized, very aggressive development actions by public officials and business leaders will be required.

Finally, the pattern of economic impacts over time is important to stable and sustained growth. In this regard, it is noted that the annual operating impacts tend to be about 55 percent or more of the annual average impacts during the construction period. Further, while preliminary data do not allow specific projections, current expectations are that the operating period benefits will increase over time as a result of ridership growth and, perhaps, other structural economic changes. The consequent conclusion is that HSR could make a sustained and probably increasing contribution to economic growth statewide and in the urban areas served.

TABLE 14-6

INCREASED ECONOMIC GROWTH RATES FROM HSR

	Alternative			
	C	C-Electric	D	E
Employment				
Construction Period	20%	24%	64%	68%
Operating Period	23	23	27	35
Personal Income				
Construction Period	4	5	14	15
Operating Period	5	5	5	7
Gross State Product				
Construction Period	4	5	14	15
Operating Period	5	5	5	7
State Revenue				
Construction Period	9	10	30	31
Operating Period	10	10	11	15

References

1 Choices for Pennsylvanians--Final Report, Pennsylvania State Planning Board, Commonwealth of Pennsylvania, Harrisburg, December 1980, p. 1.

2 Ibid., pp. 2-3.

3 The Economic Impact of Travel on Pennsylvania, 1982, Bureau of Travel Development, Pennsylvania Department of Commerce, Harrisburg, August 1983.

4 David Shih, "Pennsylvania Travel Expenditures, 1982," Pennsylvania Travel Review, Vol. 4, No. 3, Pennsylvania Department of Commerce, Harrisburg, August 1983.

5 Regional Input-Output Modeling System, Bureau of Economic Analysis, U.S. Department of Commerce, Washington, April 1981.

6 Choices for Pennsylvanians—Technical Edition, Pennsylvania State Planning Board, Harrisburg, December 1980, Appendix. Annual average growth rates were calculated based on the 1980 estimates and 1990 projections of economic activity.

7 Ibid.

8 The Economic Impact of Travel on Pennsylvania, 1982, Executive Summary, Bureau of Travel Development, Pennsylvania Department of Commerce, Harrisburg, January 1983.

9 Shih, Op. cit.

CHAPTER 15
ENVIRONMENTAL EVALUATION

This chapter describes the environmental review process that a Pennsylvania HSR project would be required to undertake and evaluates, in a general way, the likely environmental effects alternative HSR approaches would have. When possible, distinctions between alternatives that can be made on the basis of their physical impacts are identified.

15.1 FEDERAL AND STATE REQUIREMENTS

Congress and state legislatures have enacted extensive legislation during the last several decades designed to protect and enhance the environment. The result is that governmental agencies and organizations, as well as the private sector, are required to create and maintain environmental standards recognizing present and future ecological and social needs.

The National Environmental Policy Act of 1969 (NEPA), in particular, established broad national environmental goals. Two major developments resulted from this act: (1) the Council of Environmental Quality (CEQ) was established to provide general oversight of national policy, and (2) Section 102(2)(c) of NEPA specifically requires preparation of a comprehensive Environmental Impact Statement (EIS) for every federal action significantly affecting the quality of the environment. In Pennsylvania, Legislative Act 120 established procedures for the environmental review and approval process for transportation projects. In addition to the broad policy objectives established by NEPA and Pennsylvania Act 120, a multitude of federal and state legislative and regulatory actions mandate specific environmental requirements. Table 15-1 summarizes the major state and federal statutes, requirements and agencies for coordination that would be involved in the environmental processing of an HSR system in Pennsylvania.

15.2 ENVIRONMENTAL IMPACTS

Environmental impacts can generally be classified in the following primary categories:

- land use
- aesthetic intrusion
- noise and vibration
- electromagnetic interference
- air quality
- energy consumption

In addition, water resource, fish, wildlife, historic preservation and public safety issues are often considered in the environmental review process.

Although the ecological effects associated with building and operating an HSR system would be significant, they would be generally less severe than the impacts associated with building new freeways or airports. In virtually all categories--land required, energy consumption, noise, vibration, air pollution and aesthetic intrusion--railroads are potentially less damaging to the environment than airports or freeways. The following brief discussions highlight the major impacts and measures

TABLE 15-1

FEDERAL AND STATE ENVIRONMENTAL REQUIREMENTS

Area of Environmental Concern	Federal Statute	Commonwealth of Pennsylvania Statute	Requirements	Agencies for Coordination	
				Federal	State
Air Quality	Clean Air Act of 1970, Clean Air Act Amendments of 1977	Air Pollution Control Act of 1960	Sources of potential air pollution must meet primary and secondary National Ambient Air Quality Standards (NAAQS). Air pollution control programs are primarily implemented through Pennsylvania Department of Environmental Resources rules and regulations and State Implementation Plan (SIP) for Air Quality.	U.S. Environmental Protection Agency, Region III	Pa. Dept. of Environmental Resources, Bureau of Air Quality Control
Noise	Title 40, Code of Federal Regulations (CFR), Part 201 and Title 49, CFR Part 210		Sound emitted by rail cars and locomotives operated by a common carrier may not exceed prescribed standards established by federal code. New locomotives must be certified to be in compliance. State and local jurisdictions are empowered to enforce the standards.	U.S. Department of Transportation, Federal Railroad Administration U.S. Environmental Protection Agency	
Water Resources:					
Wetlands	Clean Water Act of 1977, Section 404; Executive Order 11988, May 26, 1977	Dam Safety and Encroachment Act of 1978	Section 404 of the federal Clean Water Act of 1977 gives the U.S. Army Corps of Engineers authority to regulate dredged and fill materials in navigable waters, including wetlands. The Pennsylvania Dam Safety and Encroachment Act of 1978 provides the Pennsylvania Department of Environmental Resources with procedures for permitting dams and reservoirs, obstructions and encroachments affecting streams and wetlands.	U.S. Army Corps of Engineers, Ohio River Basin: Pittsburgh District Susquehanna River Basin: Baltimore District Delaware River Basin: Philadelphia District	Pa. Dept. of Environmental Resources, Bureau of Dams and Waterways Management
Floodplains	Watershed Protection and Flood Protection Act of 1954; National Flood Insurance Act of 1968 (amended 1973)	Floodplain Management Act of 1978; Stormwater Management Act of 1978	The federal Watershed Protection and Flood Prevention Act of 1954, as well as several other federal flood control acts, authorizes the U.S. Army Corps of Engineers and U.S. Soil Conservation Service to participate in a variety of flood control and stream improvement activities. The National Flood Insurance Act of 1968, as amended, provides a nationwide program of federally subsidized flood insurance, conditioned upon active flood plain management and regulation of the floodplain development by state and local government. The Pennsylvania Floodplain Management Act of 1978 requires flood-prone comunities to develop floodplain development ordinances which meet the requirements of the National Flood Insurance program. The Pennsylvania Stormwater Act of 1978 requires counties to prepare stormwater	U.S. Army Corps of Engineers, (same as above) U.S. Dept. of Agriculture, Soil Conservation Service Federal Emergency Mgmt. Agency	Pa. Dept. of Community Affairs, Bureau of Community Planning Pa. Dept. of Environmental Resources, Bureau of Dams and Waterways Mgmt. Bureau of Resources Planning

TABLE 15-1 (cont'd)

Area of Environmental Concern	Federal Statute	Commonwealth of Pennsylvania Statute	Requirements	Agencies for Coordination	
				Federal	State
Floodplains (cont'd)			management plans to control accelerated stormwater runoff. These programs are administered by the Pennsylvania Departments of Community Affairs and Environmental Resources.		
Water Pollution Public Water Supply, Groundwater	Safe Drinking Water Act of 1974, Clean Water Act of 1977, Water Pollution Control Act of 1972, Surface Mining Control & Reclamation Act of 1977, Delaware River Basin Compact of 1961, Susquehanna River Compact of 1968	Purity of Waters Act of 1905; Clean Streams Law of 1937, amended 1977; Sewage Facilities Act of 1966; Water Rights Act of 1939	The Federal Clean Water Act of 1977 provides for the restoration and maintenance of the chemical, physical and biological integrity of waters. The formation of regional intergovernmental compact agencies as a result of the Delaware River Basin Compact and the Susquehanna River Compact provided for management of water and related resources in the river basins. The federal Water Pollution Act of 1972 provided a beginning for the coordination of surface water and groundwater pollution control programs. The federal Safe Drinking Water Act of 1974 and the federal Surface Mining Control and Reclamation Act of 1977 also provide measures to protect water quality and the groundwater resource. The Pennsylvania Clean Streams Law provides a comprehensive legislative framework for controlling water pollution. The Pennsylvania Land and Water Conservation and Reclamation Act of 1968 provides for the correction of acid mine drainage problems. Pennsylvania Department of Environmental Resources regulations provide controls of non-point source pollution problems including Chapter 73 (Sewage Disposal), Chapter 75 (Solid Waste Management), Chapter 77 (Mining), and Chapter 102 (Erosion Control).	U.S. Environmental Protection Agency, Region III Delaware River Basin Commission Susquehanna River Basin Commission Ohio River Valley Water Sanitation Commission	Pa. Dept. of Environmental Resources Bureau of Water Quality Management Bureau of Resources Programming Bureau of Community Environmental Control
Streams, Lakes Reservoirs and Special Protection	Clean Water Act of 1977, Section 404; Water Pollution Control Act of 1972; Delaware River Basin Compact of 1961; Susquehanna River Basin Compact of 1968, Safe Drinking Water Act of 1974, Federal Surface Mining and Reclamation Act of 1977, Federal Wild & Scenic Rivers Act of 1968; Watershed Protection & Flood Prevention Act of 1954; Coastal Zone Manage-	Dam Safety and Encroachment Act of 1978; Clean Streams Law of 1937; Sewage Facilities Act of 1966; Purity of Water Act of 1905; Land & Water Conservation Act of 1968	The avoidance of degradation of water quality before it occurs provides the basis for most of the federal and state legislation regarding streams, lakes and reservoirs. The federal Clean Water Act of 1977 and Pennsylvania's Clean Streams Law of 1937, amended 1977, are based on this premise. In coordination with the U.S. EPA, the Pennsylvania DER administers the state's program to avoid degradation of streams through its rules and regulations and through the state Water Quality Management Plan. Impacts on streams and waterways resulting from construction activities are regulated by U.S. Army Corps of Engineers in coordination with the Pennsylvania DER. Section 404 of the Federal Clean Water Act requires the regulation of disposal of dredged and fill materials in navigable waters. Pennsylvania DER Chapter 105 permits must also be obtained relative to waterway encroachments, and as appropriate, coordination must	U.S. Environmental Protection Agency, Region III U.S. Army Corps of Engineers U.S. Dept. of Agriculture Soil Conservation Service U.S. Dept. of Interior, National Park Service Mid-Atlantic Region U.S. Fish and Wildlife Service U.S. Coast Guard, Second Coast Guard District, Third Coast Guard District	Pa. Dept. of Environmental Resources, Bureau of Water Quality Mgmt. Bureau of State Parks Bureau of Soil and Water Conservation, Bureau of Resources Planning Bureau of Mining and Reclamation Pa. Fish Commission Fisheries & Environmental Services Pa. Dept. of Transportation, Environmental Quality Division

TABLE 15-1 (cont'd)

Area of Environmental Concern	Federal Statute	Commonwealth of Pennsylvania Statute	Requirements	Agencies for Coordination	
				Federal	State
Streams, Lakes Reservoirs and Special Protection (cont'd)	ment Act of 1972; River & Harbor Act of 1899		also be undertaken with the U.S. Coast Guard, U.S. Fish & Wildlife Service and Pennsylvania Fish Commission. Much of this coordination will include the Pennsylvania Department of Transportation and federal transportation agencies, including the Federal Railroad Administration, Federal Highway Administration, and Urban Mass Transit Administration.	Federal Highway Administration Urban Mass Transportation Administration Federal Railroad Administration, Environmental & Special Projects Office	
Fish and Wildlife:					
Fish and Wildlife Resources, Habitat Preservation, Protection and Management, Endangered and Threatened Species	Fish and Wildlife Coordination Act of 1934; Pittman-Robertson Act (1937); Dingell-Johnson Act (1950), Endangered Species Act of 1973	Title 30 (Fish) Pennsylvania Consolidated Statutes; the Fish Law of 1959; Game Laws, Administrative Code of April 9, 1929, P.L. 177 & 1902-A, Section 2002	The federal Fish and Wildlife Coordination Act requires coordination with the U.S. Fish and Wildlife Service and state wildlife agencies on any stream modification. Coordination is also required by the federal Endangered Species Act to ensure listed species and critical habitat are not jeopardized by proposed actions.	U.S. Fish and Wildlife Service	Pa. Fish Commission, Fisheries and Environmental Services Pa. Game Commission
Agricultural Lands:					
Prime and Unique Agricultural Lands, Farmland of Statewide Importance		Act 100 (1979); Act 442 (1968); Act 284 (1968) amending municipalities Planning Code (Act 247); Act 43 (1981)	Pennsylvania Act 100 of 1979 requires approval of transportation projects as well as solid waste management projects requiring the taking of agricultural lands. An erosion and sedimentation control plan consistent with the Pa. Soil and Water Conservation Plan is required for all earth-moving activities. Both the Pa. DER and the Soil Conservation Districts have approval responsibilities for erosion and sedimentation control plans.	U.S. Dept. of Agriculture, Soil Conservation Service	Pa. Dept. of Agriculture Pa. Dept. of Environmental Resources, Bureau of Soil and Water Conservation, Bureau of Water Quality Management Local County Conservation Districts (as appropriate)
Forests and Woodlands	Cooperative Forestry Assistance Act of 1978	Administrative Code of 1929	The DER is authorized to require and manage land as State Forest Land, protect all forest land from fire, insects and disease and provide technical assistance to municipalities and other land owners. The federal Cooperative Forestry Assistance Act authorizes the U.S. Department of Agriculture to assist the State Forester in advancing forest resources management, programs and technology.	U.S. Dept. of Agriculture, Forest Service	Pa. Dept. of Environmental Resources, Bureau of Forests
Parks, Gamelands, Natural Areas & Open Space	Land and Water Conservation Fund Act of 1965; Act of August 21, 1935, (16 U.S.C. 461); National	Land and Water Conservation and Reclamation Act of 1968; Assessment of Open Space Act of	Section 4(f) of the U.S. DOT Act requires the the U.S. Secretary of Transportation will not approve any project or program that will use land from a public park, fowl refuge, or any land from an historic site of national, state or local significance as determined	U.S. Dept of Interior: National Park Service Mid-Atlantic Region U.S. Fish and Wildlife Service	Pa. Dept. of Environmental Resources Bureau of Forestry Bureau of State Parks Pa. Department of

TABLE 15-1 (cont'd)

Area of Environmental Concern	Federal Statute	Commonwealth of Pennsylvania Statute	Requirements	Agencies for Coordination	
				Federal	State
Parks, Gamelands, Natural Areas & Open Space (cont'd)	Wild & Scenic Rivers Act of 1968; Section 4(f) of U.S. Department of Transportation Act. National Trails System Act.	1965; Act 442 of of 1968; Administrative Code of April 9, 1929 (P.L. 177-1902A) Scenic Rivers Act of 1972.	by the responsible officials unless there is no feasible or prudent alternative to the use of such land, and all possible planning has been taken to minimize harm from the proposed taking. The Federal Land and Water Conservation Fund Act provided funds for acquiring and developing parks, open-space areas and recreation facilities. In addition to requirements under Section 4(f), any public lands acquired under the Land and Water Conservation Fund Act requires replacement with lands of similar qualities and values. The act of August 21, 1935 authorized the National Park Service to establish the National Natural Landmarks Program. The National Wild and Scenic Rivers Act protects rivers of outstanding wilderness values. The National Trails System Act provides for the development of rural and urban trails. Much of Pennsylvania's regulation of natural areas stems from the Administrative Code of 1929 (P.L. 177) which authorizes these activities by the Department of Natural Resources. Pennsylvania's Scenic Rivers Act and Land and Water Conservation and Reclamation Act have provided for the acquisition and development of public parks and recreation facilities. The Assessment of Open Space Act of 1965 and Act 442 of 1968 provides measures to acquire, protect and preserve open space uses.	U.S. Dept. of Agriculture, Soil Conservation Service Forest Service U.S. Dept of Transportation, Federal Highway Administration Urban Mass Transportation Administration Federal Railroad Administration, Environmental and Special Projects Division U.S. Dept. of Housing and Urban Development, Philadelphia Area Office Pittsburgh Area Office	Community Affairs Bureau of Recreation and Conservation Pa. Game Commission Pa. Fish Commission Fisheries and Environmental Division Pa. Dept. of Transportation, Environmental Quality Division
Historic and Archeological Resources	National Historic Preservation Act of 1966, Section 106; Section 4(f) of the Department of Transportation Act, Executive Order 11593, May 13, 1971		In addition to public parks, recreation areas and wildlife and waterfowl refuges, Section 4(f) involvements also include the taking of land from historic sites of national, state and local significance as determined by the responsible officials. A determination must be undertaken to establish that there are no feasible or prudent alternatives to the proposed acquisition of land from the site of historic significance and that the planning of the project or program includes measures to minimize harm resulting from the proposed taking. The determination and historic preservation officials of the federal and state levels. Section 106 of the National Historic Preservation Act requires that the head of any federal agency having direct or indirect jurisdiction over a proposed federal or federally assisted undertaking in any state and the head of any federal department or independent agency having authority to license any undertaking shall, prior to the approval of the expenditure of any federal funds on the undertaking or prior to the issuance of any license, as the case may be, take into account the	Advisory Council on Historic Preservation U.S. Dept. of Interior, Keeper of the National Register of Historic Places National Park Service, Mid-Atlantic Region U.S. Department of Transportation, Federal Highway Administration, Urban Mass Transportation Administration, Federal Railroad Administration Environmental and Special Projects Office	Pa. Historical and Museum Commission, Bureau of Historic Preservation Pa. Department of Transportation, Environmental Quality Division

TABLE 15-1 (cont'd)

Area of Environmental Concern	Federal Statute	Commonwealth of Pennsylvania Statute	Requirements	Agencies for Coordination	
				Federal	State
Historic and Archeological Resources (cont'd)			effect of the undertaking on any district, site, building, structure, or object that is included in the National Register of Historic Places. The Advisory Council on Historic Preservation shall be afforded the opportunity to comment with regard to such undertaking.		
Transportation Planning, Area-Wide Comprehensive Planning and Development	Urban Mass Transportation Act of 1964; Clean Air Act of 1970 and Clean Air Act Amendments, 1977; Highway Act (23 U.S.C. 134); Title IV of Intergovernmental Cooperation Act; OMB Circular A-95; Title VI of Civil Rights Act of 1964; Surface Transportation Assistance Act of 1982	Pennsylvania Transportation Act 120	For urban areas with populations over 50,000, transportation projects and programs must be based on continuing, comprehensive and cooperative (3-C) planning process by state and local communities. The A-95 clearinghouse process provides for state and local review of proposed federal and federally assisted programs and projects in terms of potential impact or conflict with statewide, areawide or local plans and programs. The Clean Air Act, as amended, requires conformity to State Implementation Plan (SIP). Pennsylvania Transportation Act 120 requires a review with publication of the findings in the Pennsylvania Bulletin subsequent to the state's environmental clearance. The federal Civil Rights Act and the Surface Transportation Assistance Act require consideration of minorities and other special groups relative to impacts or participation in project planning and implementation.	U.S. Department of Transportation, Federal Highway Administration, Urban Mass Transportation Administration, Federal Railroad Administration, Environmental and Special Projects Office U.S. Dept. of Housing and Urban Development	Pa. Department of Transportation Pa. Department of Community Affairs, Bureau of Policy Development Pa. Dept. of Commerce, Economic Development Pa. Dept. of Environmental Resources Pa. Human Relations Commission Pa. Dept. of Aging Bureau of Policy, Planning & Monitoring Appropriate MPO and A-95 Clearinghouses

that can be taken to minimize them. Also discussed are potential environmental benefits.

15.2.1 Land Use/Aesthetic Intrusion

The ecological consequences of building an HSR system would be significant. Landowners, particularly, are likely to object to the aesthetic intrusion, the noise and vibration inherent in the construction and operation of such a system adjacent to their property, and the resulting effect on property values. Environmental impact, of course, accompanies any new transportation system installation, but it is more acutely felt in the case of systems being proposed through highly urbanized areas, farm lands and/or recreational areas.

The impacts and intrusions can be minimized by careful site selection and route alignment along existing transportation corridors--e.g., by paralleling interstate highways or existing rail lines, by installing sound barriers along the right-of-way and incorporating shock-absorbing elements in the design, or by locating the track on an elevated structure or underground. But these measures have limitations. Tunneling can be 10 to 25 times more expensive than at-grade construction, and, therefore, cannot be used extensively to alleviate environmental impacts. Sufficient land may not be available adjacent to (or in the median strip of) urban freeways to locate the HSR system there, and sound barriers have only limited effectiveness.

One of the more promising mitigation measures involves elevating the system (particularly under Alternative E) so that merely an easement, rather than outright property acquisition, would be required. This configuration would be particularly advantageous through open space and agricultural areas where the high-speed system need not influence present land use. Farming, for instance, could be continued in areas immediately adjacent to the elevated guideway under this approach.

Detailed site-specific trade-off analyses must be conducted and coordinated with local planning authorities and citizen groups to identify a system alignment and design that is environmentally acceptable to potentially affected residents. This can be time-consuming and expensive, but cannot be avoided.

The proposed new Susquehanna River crossing in the vicinity of the existing Rockville Bridge, just north of Harrisburg, appears to offer a challenge from the standpoint of visual quality. Detailed design studies may be necessary to determine the consensus of design views on the nature of the new crossing in relation to the existing historic facilities and scenic vistas. Tunnels have been proposed in the vicinity of Middletown, Highspire and Marysville where the most desirable alignments would otherwise affect existing downtown development and land use patterns, as well as yielding negative visual impacts. In other areas, the use of elevated structures has preserved the existing land use, requiring only easements for construction and operation. Also, wherever possible, the joint use of existing transportation corridors has been proposed. Locations along Pennsylvania Route 283, U.S. Route 220, relocated U.S. Route 22, and portions of the Pennsylvania Turnpike have been used where the prevailing grades are or could be made consistent with specific design criteria for the rail technologies.

Several categories of land require special environmental consideration as discussed below.

Parks, Recreational Areas, Wildlife Refuges, Open Space and Natural Areas

Section 4(f) of the U.S. Department of Transportation Act of 1966 provides that no transportation action will use land from a significant publicly-owned park, recreation area or wildlife and waterfowl refuge or any significant historic site unless a determination is made that: (1) there is no feasible or prudent alternative to the use of land from the property; and (2) the proposed action includes all possible planning to minimize harm to the property resulting from such use. Lands typically protected by Section 4(f) include national, state and municipal parks and recreational lands, lands specifically designated as wildlife and water fowl refuges, and historic sites and properties which are listed on, or determined to be eligible for listing on, the National Register of Historic Places. In Pennsylvania, state game lands are protected under Section 4(f); for the most part, however, state forest lands are not.

As proposed, only about six miles of new alignment (under Alternatives D and E) pass through state-owned lands, defined by Section 4(f) as mostly state game lands. No federally-owned lands appear to be involved, and initial evaluations indicate that no acquisitions would be necessary from state forest lands. Acquisitions from county- or municipally-owned lands protected by Section 4(f) have not been determined at this level of the study. Some conflicts can be avoided by shifting alignments slightly from those initially developed. It is also unlikely that construction within the existing rights-of-way would require the taking of additional Section 4(f) land.

Alternative E crosses a portion of Marsh Creek State Park. Several alignments were investigated that did not cross the park, but each significantly lengthened total trip time. Additional alignments can later be investigated and mitigation measures proposed to minimize disruption to this resource.

Prime Agricultural Lands

The proposed new alignments cross several areas classified as prime agricultural lands. In certain of these areas, use of an elevated guideway would minimize the impact. Further study of the location of these alignments may suggest using lands that are less productive. It is anticipated that improvements within existing rights-of-way will not affect productive farmlands.

The provision of measures to control runoff from construction areas, both on new and existing rights-of-way, however, is a primary concern to agencies responsible for agricultural activities. These agencies must approve the erosion and sedimentation control plans prepared for the project.

Because of the large amount of farmland that may be affected by the proposed HSR project, and to ensure that measures are taken to minimize adverse effects on the agricultural economy, coordination and consultation will have to be carried out with the agencies responsible for agricultural affairs. Since most of the counties affected have significant agricultural resources, the coordination and consultation process must extend to this county level. The agricultural industry itself is strongly organized in Pennsylvania, and these representative organizations are important sources of information on preferable alignment routing.

Forest and Woodlands

Forests and woodlands occupy a significant portion of the proposed rail corridor. Except for certain areas in the state forest land system, which are specifically designated for recreational use and as wildlife preservation areas, state forest lands do not qualify as lands protected under Section 4(f) of the federal act. State forest lands, however, are protected by state legislation and regulations, and acquisitions of these lands require evaluation under Pennsylvania Act 120. A review of the proposed alignments at this level of study, however, indicates that all known state forest lands can be avoided.

Environmental interest, however, extends to privately-owned forests and woodlands. Much of this land is in productive commercial use, although some is reserved for future commercial production. Timber is a renewable resource, although a considerable span of time is necessary to bring a previously harvested area back into production. Lands that are not commercially productive or are held in reserve frequently have other uses, including "second home" development, recreation and natural and wild areas.

Pennsylvania Act 100 is applicable to much of the privately-owned woodlands in Pennsylvania. There are also other cooperative state-private programs related to the management of forests and woodlands designed for the preservation of these lands, to improve their management and protection, and fulfill the recreational and natural resources protection potentials of these lands. As a consequence, there are requirements to coordinate and consult with the agencies and officials responsible for the forest resources, as well as with the owners of these lands and representatives of the forestry industries. Appropriate mitigation will be necessary to minimize impacts on these lands and their associated uses.

15.2.2 Noise and Vibration

All the systems under consideration use high-technology equipment that is inherently quieter than the majority of existing rail equipment. Tighter construction tolerances for track will tend to minimize wheel/rail noise, the diesel-electric locomotives use state-of-the-art blower and exhaust noise transmission controls, and the electrically-powered alternatives minimize propulsion noise. Noise impacts from high-speed operations should be relatively minor, particularly given the low number of trains per day envisioned.

Electric trains are quieter than conventional diesel-electric trains, but they still can produce potentially unacceptable levels of noise at high speeds--more than 90 dB(A) at 100 feet, for trains operating in excess of 120 mph.[1] Steps can be taken to attenuate and reduce noise and vibration, for example, by installing continuous welded rail, elastomeric track pads, "floating" slabs, acoustical barriers, and so on. Nevertheless, these measures alone may be insufficient. Japanese National Railways have found that, in some cases, the only way to reduce noise to an acceptable level in densely populated areas (where houses are close to the tracks) is to reduce speed. Even though the Shinkansen is designed for a top speed of 160 mph, trains are not operated at above 130 mph in revenue service, or even at that speed in heavily built-up areas. Reportedly, this is in part because of noise and vibration problems encountered at higher speeds.[2]

Maglev systems are potentially more attractive environmentally than conventional or high-speed rail, because there is no contact between vehicle and guideway to generate noise and vibration; however, the aerodynamic noise of a train traveling 250 mph or more is high--in the range of 96-110 dB(A).[3] At lower speeds of 150 to 200 mph, a Maglev system could operate in the very acceptable range of 65-70 dB(A).[4]

Operations of the proposed HSR system must conform to the railroad noise emission compliance regulations jointly promulgated by EPA and FRA.[5] During construction, compliance with noise control standards provided by local ordinances must also be assured. For Alternatives B and C, it is assumed that the equipment will conform to the present criteria. For the HSR and Maglev alternatives, it will be necessary to assure that the high-speed trains will be in compliance with the standards. In the extreme, waivers might have to be sought if compliance with the existing standards could not be attained. This is not expected to be the case, however.

15.2.3. Electromagnetic Interference

Electrified railroads generate electromagnetic disturbances along the right-of-way that can affect telecommunication, especially in cables used for voice telephony, but techniques for dealing with this problem are well known. Not well known are the potential effects of the strong magnetic fields generated by magnetic levitation systems. Shielding may have to be provided both in the vehicle and around the structure to mitigate these potential effects.

15.2.4 Air Quality/Energy Consumption

Two bright spots in the HSR environmental impact picture are air quality and energy consumption.

Air pollution from railroads is not a major problem. When railroads are electrified, emissions associated with burning fuel for traction are confined to centralized power plant locations. There, emission levels vary by type of energy source and degree of environmental controls applied.[6] In any case, the level of pollutants emitted to power rail passenger vehicles is miniscule, compared to emissions from other transportation modes, notably highway vehicles.

As the result of the measures taken to comply with the federal Clean Air Act, significant progress has been made in improving air quality throughout the Pennsylvania Corridor. It is only in the major urban areas, especially Philadelphia and Pittsburgh, where attainment and maintenance of the National Ambient Air Quality Standards remain a major problem. The Pennsylvania State Implementation Plan, prepared in compliance with Section 110 of the Clean Air Act, provides measures to ensure the attainment and maintenance of the standards. In the designated non-attainment areas, specific measures must be applied to reduce the pollutant level below the established standard. For pollutant emissions from transportation sources, transportation control measures, designed to reduce pollutant emissions from these transportation sources, are indicated in the state plan.

The EPA is the primary federal agency responsible for the actions and measures to be taken to comply with the Clean Air Act requirements. Federal transportation agencies also have assumed a major role in fulfilling requirements of the Act because many of the air pollutant emissions are generated from transportation sources.

HSR would generally improve air quality to the extent that travelers can be diverted from autos. Local effects would vary by alternative depending on traffic levels and type of prime mover used--diesel or electric.

Under the diesel-powered alternatives (B and C), a typical diesel-electric locomotive at full throttle, with 3100 delivered horsepower, would consume approximately 168 gallons of fuel per hour.[7] The following air pollutant emissions can be anticipated for the locomotive in this operating mode:[8]

Carbon Monoxide: (CO) 21.88 lb per hour
Hydrocarbons: 15.8 lb per hour
Nitrogen Oxides (NO_x as NO_2): 62.2 lb per hour
Particulates: 4.2 lb per hour
Sulfur Oxides (SO_x as SO_2): 9.6 lb per hour

For an electrified system, there would be almost no air pollutants emitted to the environment as a result of the operation of the vehicles, and, at the central power generation sources, there would be slight increases in emission levels from the additional fuel consumed to produce the electricity required for the system.

During construction of the proposed facilities, there is a possibility of adverse effects on air quality due to concentrations of construction equipment along the relatively narrow right-of-way. Particularly during earthmoving operations, airborne dust can contribute to increased particulate levels. Dust control measures are typically included in the contract specifications.

In many of the urbanized areas, a source of concern relative to impact on air quality may be changes in the traffic volumes and circulation patterns at the stations and on the streets and roadways that provide station access. If parking is increased at stations because of the patronage of the HSR system, not only will joint planning with the community have to be undertaken to assure the additional parking spaces, but the related effects on air quality will have to be considered. These aspects will require coordination and consultation with community officials and planning agencies as details of the proposed project are developed.

Relatively low energy consumption is another benefit of rail travel, although at higher speeds, the consumption rate rises sharply. Relative modal energy consumption at cruising speed is shown in Table 15-2. These consumption rates indicate the relative modal efficiencies under ideal conditions. They do not reflect acceleration or braking energy rates, nor are they representative of actual consumption rates that could be experienced in the Pennsylvania Corridor, with grades, curves and intermediate station stops. (Alternative-specific estimates for selected HSR equipment types, operating in the Pennsylvania Corridor were shown in Table 5-3. These estimates cannot be directly compared with those of Table 15-2.)

Modal efficiency should really be measured in terms of energy consumption per passenger-mile, rather than per seat-mile; however, this requires that vehicle loading be factored in, and load factors can vary significantly by time of day, trip purpose, etc. Nevertheless, to talk in a meaningful way about "energy savings," one must consider passenger loading in the calculation.

TABLE 15-2

MODE SPECIFIC CRUISE ENERGY CONSUMPTION[9]

Vehicle Mode	Specific Energy Consumption btu/seat mile
Automobile (4 passengers @ 60 mph)	1,400
Bus (43 passengers @ 60 mph)	490
HSR (382 passengers @ 160 mph)	1,000
Maglev (382 passengers @ 300 mph)	2,000
Boeing 747 (385 passengers @ 580 mph)	2,200
DC-9-30 (115 Passengers @ 565 mph)	3,750

Of possible concern is the amount of energy to be consumed in construction, reconstruction and renovation that are necessary to provide the improvements for the proposed system. Given the diverse nature of the construction requirements for the implementation of the various alternative alignments and configurations proposed, it is difficult to estimate the associated construction energy requirements. Such estimates have not been prepared in this study. Energy expenditures for maintenance of the system, when compared to energy requirements for construction and operation, are negligible.

Since some proposed HSR alternatives will be powered by electricity, the availability of sufficient generated electrical power to supply the system is of concern. Although the electrical energy requirements for the project have not been finally established at this time, it is apparent that current electrical generation capacity could easily supply the system's needs.

15.2.5 Safety

If well maintained and operated, rail systems have excellent safety records. The U.S. Department of Transportation reports a rail fatality rate of 0.13 per 100 million passenger-miles, compared to 1.3 per 100 million passenger-miles for automobile travel in 1979--an order of magnitude difference.[10] HSR is potentially even safer than conventional rail. The Japanese Shinkansen, for instance, has carried 2 billion passengers over a period of 20 years without a single fatal accident--the best safety record by far of any transportation system ever built by man. Advanced signal systems, attention to maintenance, common equipment (no freight), and elimination of grade crossings all contribute to the improved safety characteristics of HSR.

Maglev is unproven but potentially safer than either conventional or high-speed rail, since it is being designed to preclude any possibility of derailment or train collision.

Because vehicles will be operated on the guideways at very high speeds, measures to provide for the safety of passengers and operating crews must be assured. Inspection and maintenance of the equipment and the guideway must be provided on a continuous ongoing basis, with considerations to advanced monitoring systems, including use of electronic and televisual surveillance and warning technologies. The HSR system should be fully fenced to prevent people, livestock and wildlife from entering the right-of-way, except where the guideway is elevated and other activities can be safely carried out below the structure. Safety and security measures must also be included to prevent debris from being thrown into the path of the vehicles from overpasses and to prevent other acts of vandalism which would jeopardize safety during operations. The physical safety and security of patrons in the station areas are also issues for which protective planning must be undertaken. Police protection should be provided throughout the system, with consideration of the availability of municipal and/or specially formed police units in the major municipalities.

15.2.6 Water Resources, Fish and Wildlife

For sections of the proposed HSR system that will remain within existing rights-of-way, there is little probability of significant water-related impacts. In these areas, however, if reconstruction or widening of stream crossing structures affects the stream or its water quality, the necessary coordination and permit approval procedures will still be required. Depending on the type and nature of reconstruction activities within the right-of-way, measures such as the preparation of an erosion and sedimentation control plan may be necessary.

The proposed HSR alternatives that involve the use of new rights-of-way may adversely affect streams and drainage areas throughout the project area. Alternatives D and E are 50 percent and 30 percent on existing right-of-way, respectively. Measures will have to be taken to assure that construction, maintenance and operation of the system on these alignments do not adversely affect water quality and resources. Coordination and consultation with the officials and agencies with water-related responsibilities will be necessary to obtain required approvals and permits.

Wetlands

In recognition of the unique ecological role of wetlands, specific executive action and agency directives have instituted procedures to ensure the protection and preservation of these areas. An initial evaluation indicates that very little of the wetlands identified in previous inventories will be affected. Coordination will be necessary to conclusively identify and classify wetlands that may be affected by the proposed alternatives. Mitigation measures for the elimination or reduction of adverse effects on wetlands will be identified and undertaken, as necessary.

Floodplains

Historically, the floodplain areas of Pennsylvania have attracted development because of the proximity of rivers, availability of lumber for building, and the relatively flat terrain that these areas provide. The development of transportation systems, especially railroads, has extensively followed the rivers and streams, as the floodplains along these features provided easy grades through the mountainous terrain, reducing earthmoving requirements. As the transportation systems were developed to serve communities and industry located in the floodplains, these systems have attracted further development, compounding the problems associated with flood susceptibility. As a result, measures are being undertaken by the federal and state governments to discourage further development in the most acutely affected areas and to provide compensation when losses occur due to flooding disasters.

These requirements mandate extensive coordination and consultation with the Corps of Engineers, the Federal Emergency Management Agency, the Pennsylvania Departments of Environmental Resources and Community Affairs, the affected communities, and other concerned agencies such as the Soil Conservation Service, to resolve floodplain development issues and to obtain the necessary permits and approvals.

Both reconstruction within the existing right-of-way and construction on new locations will be of concern as regards floodplain impact. Because the proposed realignments generally would move the railroad away from the floodplains, the opportunity exists to reduce the severity of flooding that the rail system may have aggravated in the past.

Fish and Wildlife Effects

Coordination and consultation with the U.S. Fish and Wildlife Service, the Pennsylvania Fish and Game Commissions and the affected local municipalities is necessary as a result of legislative and regulatory requirements. Information from these agencies also will be necessary in the Section 4(f) evaluations, which must be prepared when right-of-way is to be acquired from lands designated as wildlife and waterfowl refuge, or which may be identified as publicly-owned recreational areas. State game lands, which are affected by all of the proposed relocation alternatives, are included within the Section 4(f) definitions as are many of the other national, state and locally owned lands which meet the Section 4(f) criteria.

15.2.7 Historic Preservation

The National Historic Preservation Act of 1966 provides measures and procedures to ensure the protection and preservation of places and properties designated as historically and archeologically significant. Section 106 of this act establishes closely defined review procedures to be followed when properties on, or eligible to be on, the National Register of Historic Places may be affected by the proposed action.

An initial survey indicates that more than 1,050 sites and properties are on, or eligible for, the National Register in the selected 22-county area. It was estimated that only a limited number of these sites or properties would be affected. However, with the passage of time, features of the transportation system itself sometimes achieve historical significance in the areas of engineering, architecture and transportation. The Rockville Bridge and the Horseshoe Curve, both on the existing alignment, are listed on the National Register. Many of the existing stations are also on, or eligible for inclusion on, the National Register. Renovation of existing station structures for use by the HSR system will require recognition of this fact. The existing alignment runs through or near many areas designated as historic districts. The circumstances that have caused the existing facility to be located in floodplains and areas paralleling streams have placed these alignments in areas of known or suspected archeological significance. In general, however, where the HSR system will remain within the existing right-of-way, it is assumed that the renovation measures will have little or no effect on those features integral to the system which are accorded historic recognition, or on adjacent or nearby historically significant sites or properties. For new alignments, extensive investigation may be necessary to identify and inventory Register-eligible properties, and to determine the probable effects that the project may cause. The determination of archeologically significant sites generally is much more difficult than the above-ground sites of historical significance. These investigations must include consultation and coordination with the State Historic Preservation Office/Pennsylvania Historical and Museum Commission, the Keeper of the National Register, which is a function of the Department of the Interior's National Park Service, and the Advisory Council on Historic Preservation, the federal-level organization charged with matters related to the protection and preservation of properties significant to the nation's heritage.

15.3 MITIGATION MEASURES

This subsection explains the need for mitigation measures and their relationships to other elements in the development of the proposed HSR system. At this level of the study, the discussion is primarily an introduction to these measures. The measures necessary to mitigate objectionable effects of the proposed system will be further developed during subsequent planning and design phases. As the effects of the project are further specifically identified, consideration must be given to mechanisms and strategies to mitigate undesirable environmental effects. Failure to provide adequate mitigation may jeopardize environmental approval of the project.

The HSR system, extending across the state, affects numerous, and widely diverse, activities and resources as discussed in previous subsections. With the wide variety of effects, as can be expected with an undertaking of the scale and scope of the HSR system, many potentially adverse impacts have already been considered. Others may become apparent as the study efforts broaden. For many of the potential impacts, federal and state legislation and regulations require mitigation. When coordination and consultation is undertaken with federal, state and local agencies and the public and communities have become involved, other impacts probably will be indicated.

To ensure that adequate levels of mitigation will be applied to overcome objectionable effects, the following approaches should be used to develop a mitigation program:

- Mitigation should be an early and continuing part of the project development process.

  As soon as effects are identified and assessed as adverse impacts, consideration of measures to adequately mitigate the objectionable aspects of the effect should commence. The ability of the project alternatives to mitigate adverse effects should be a part of the alternative selection process. The selected alternative may not necessarily be the one for which the least environmental impact is anticipated, but it certainly should be one for which adequate opportunities to satisfactorily mitigate adverse effects are presented.

- Mitigation should be integrated into the project planning and design.

Many of the opportunities to provide mitigation measures can be woven into planning and design. As a result of an integrated approach, it may be found that some impacts can be avoided entirely with minor shifts of alignments and other planning and design techniques. Many others can be more effectively addressed during these phases, and the measures provided can be applied cost effectively. Delays and cost increases should be avoided because it then becomes necessary to backtrack project design to retrofit measures for mitigation.

- Mitigation should be project-wide in scope.

  Many of the project's potential impacts may occur repeatedly throughout the length of the project. An approach that would provide mitigation to specific effects at separate and individual receptors could result in overly complex and duplicative design procedures, possibly increasing design effort and costs. Many of the impacts can be considered collectively, and the applicable mitigation measures can be standardized throughout the project's corridor, resulting in design efficiency and reducing costs. This approach could effectively reduce the effort required to provide adequate mitigation, as the number of sites at which additional site-specific mitigation would be required would be significantly reduced.

- Mitigation should be comprehensive.

  Because a number of impacts are contemplated to occur, measures should be designed to mitigate a wide range of impacts simultaneously. Each mitigation measure should reduce the impacts to as many needs as possible, thus increasing the overall effectiveness of the design.

- Mitigation must be economical.

  As the need for a comprehensive and integrated mitigation program is apparent even at this level of the study, it must be assured that the measures are cost-effective in order to be approved and funded as part of the project's construction. Mitigation measures must be appropriate to the relief of specifically-identified impacts and concerns for effects on recognized environmental sensitivities. Unrestrained project measures which provide enhancement beyond the basic needs and contribute to significant increases in project costs are to be avoided.

In summary, the consideration of each of these approaches in establishing mitigation measures for the project is directed toward improved cost effectiveness, which is essential to ensure approval of the project.

15.4 ENVIRONMENTAL PROGRAM REQUIREMENTS

Ensuring the environmental acceptability of the proposed HSR system and providing for the necessary approvals and permits represents an undertaking of significant dimension. This program must take into consideration not only the effects directly attributable to the construction, operation and maintenance of the proposed HSR system, but also effects that are indirectly related to the system. On the other hand, the program must be designed and developed for consistency with overall project budgetary and schedule considerations.

The need for documentation of the assessment of potential environmental effects, together with the requirement for agency coordination and consultation across a broad range of environmental concerns, suggests the preparation of a single overall environmental document for the project. A program-wide EIS, consistent with the CEQ standardized format and content, could be prepared and processed for the entire project. The preparation and processing of an EIS of this type is consistent with the policies and goals established by NEPA and specifically responds to CEQ and other agency efforts to reduce excessive paperwork and to make the EIS more useful in the decisionmaking process.

A programmatic EIS would fulfill many of the requirements of the environmental documentation and review process appropriate to the statewide context of the proposed HSR system. A document of this scale and scope, however, cannot be viewed as the final document for each alternative section or segment in the overall system. For alternatives, especially those relocated from existing rights-of-way, which may not have had all the environmental concerns sufficiently identified or investigated, or for which the environmental context has changed with the passage of time, site-specific EISs may be required. With the existence of a programmatic EIS, however, through the mechanism which has been termed "tiering," efforts to prepare and process subsequent site-specific EISs will be significantly reduced. The tiering mechanism is aimed at eliminating repetitive discussions of issues that have been adequately covered in the broader initial statement, and allows concentration on those issues of most concern in the site-specific statement. Tiering permits the summarization of those environmental issues for which decisions and approvals were already completed within the initial statement. The existence of a broad initial document would also permit the incorporation of relevant discussions by reference.

For certain alternative sections and segments where it is established that no significant adverse effects are likely to occur, and there are no controversial issues in the environmental context, the project may be permitted to proceed on the basis of the primary EIS. Sites that may be appropriately considered for processings of this type will include those in which construction and operations remain within existing rights-of-way, and no significant changes in environmental effects occur within the surrounding area. In these cases, the responsible authority can permit the project to proceed on the basis of the preparation and filing of a finding of no significant impact (FONSI). The existence of a programmatic EIS greatly increases the probable acceptability of the processing of site-specific projects with a FONSI.

If there is uncertainty regarding the level of processing necessary for a site-specific location, CEQ regulations provide for the preparation and processing of an Environmental Assessment (EA). The purpose of an EA is to determine whether an EIS should be prepared and processed for the proposed action. In the development of an EA, the identification, analysis, coordination and documentation processes are undertaken in much the same manner as for an EIS; however, these processes only proceed to the point at which it can clearly be decided whether it is necessary to prepare an EIS. Consequently, investigative and coordination processes are less extensive than for an EIS, agency comments in response to the EA generally originate at lower levels than those necessary for the EIS, and, because the EA is primarily directed toward an internal decision, it requires less time, effort and cost than for an EIS. If it is determined as a result of the preparation and processing of the EA that there are no significant impacts on the human environment, the project can proceed with the filing of a FONSI. If, however, it is determined that there are significant environmental effects, or that there is controversy with respect to the environmental context, an EIS must be prepared for the proposed action. The work performed during the EA phase will then serve as a foundation upon which to further construct the EIS.

The standard format recommended by CEQ for a programmatic EIS includes the following:

- Coversheet - A single page that provides the title of the proposed action; identifies the responsible agencies; indicates the location of the proposed action; designates the statement as a draft, final, or draft or final supplement; and provides a one-paragraph abstract. Also included is the name, address and telephone number of the person at the agency to be contacted for further information. The date by which comments must be received also must be provided. A signature block is provided for the agency's approval. Finally, the legislation which requires the preparation of the document is also designated.

- Summary - A brief summary is presented at the beginning of the document.

  It stresses the major conclusions, areas of controversy (including issues raised by agencies and the public) and unresolved issues. The alternatives are presented in the summary, and a choice among the alternatives is discussed.

- Table of Contents - Provides a listing of the major headings and titles. Exhibits, tables and attachments are identified.

- Purpose and Need - A presentation of underlying purpose of the proposed action and its need. This section also presents the governmental authority or legislation directing the proposed action.

- Alternatives - This section describes the proposed action in terms of the alternatives for its execution, including an explanation of how they were selected. The do-nothing alternative is always presented to explain the consequences of taking no action, and serves as an index against which many effects of the considered alternatives may be measured.

  The primary objective of this section is to list the alternatives and their environmental consequences in comparative form. This aids in sharpening distinctions among the alternatives and their related effects and provides a clear basis for choice by decisionmakers and others reviewing the document. Any measures needed to mitigate adverse effects of the proposed alternatives will be discussed.

  The preferred alternative should be indicated in the final statement if it has been conclusively determined at that stage of the project's development.

Discussion in this section is best accomplished by brief written descriptions of each alternative, supplemented with maps and other visual aids such as photographs, drawings or other graphical representations.

- Affected Environment - This section will consist of a single concise description of the existing social, economic and environmental setting of the area affected by all of the alternatives proposed. All environmentally sensitive locations or features will be identified and maps, photographs, illustrations, and other graphics will be used to enhance the readers' understanding.

- Environmental Consequences - This section will discuss the probable social, economic and environmental effects of the proposed alternatives, and measures to mitigate adverse impacts. Each of the environmental categories of concern will be treated separately with discussions of probable impacts and mitigation measures. The subsection will discuss general impacts and mitigation measures that are the same regardless of the alternative selected, eliminating repetitious discussion.

  The discussions of impacts in the draft and final EIS will include:

  - summary of studies performed and assumptions made, with sufficient data or cross-referencing to ensure validity for the methodology
  - sufficient information to establish the reasonableness of conclusions about impacts
  - discussion of mitigation measures

  When the final EIS is prepared, the effects and mitigation measures will be discussed in more detail than in the draft EIS. Both beneficial and adverse effects will be fully considered, and the discussions will be guided by response to comments and information resulting from the circulation and review of the draft EIS.

  The following is a general outline of potentially significant categories and classes of effects to be considered for discussions in the Environmental Consequences section of the EIS.

  - Social and Economic Effects - Including community effects, effects on regional and local economies and developmental opportunities, and effects on social groups such as the elderly, handicapped, minorities, etc.
  - Relocation Effects - Estimation of the numbers of households that may be displaced; estimation of number, type and size of businesses to be displaced; availability of relocation sites; and explanation of relocation assistance.
  - Air Quality Effects - Summarization of the air quality effects anticipated for the proposed alternatives, including the conformity of the proposed systems to SIP goals.
  - Noise Effects - Summarization of operational and construction noise effects anticipated for the proposed HSR system.

- Energy - Discussion in general terms, of the energy requirements and conservation potential attributable to the alternatives proposed for the HSR system.
- Land Use Effects - These discussions will center on descriptions of current developmental trends and state and local plans and policies regarding land use and growth.
- Water Quality/Resource Effects - Summarization of analyses, evaluations and consultations with responsible federal, state and local agencies for water quality and resources.
- Floodplain Impacts - In response to specific requirements, impacts on floodplains must be specifically analyzed and appropriate coordination must be undertaken with federal and state agencies, including the Army Corps of Engineers.
- Wetlands Impacts - As mandated by specific requirements, investigations and coordination will be undertaken with regard to impacts on wetlands. The required wetlands findings will be included in the final EIS.
- Coast Zone Impacts/Effects on Wild and Scenic Rivers - There are also statutory requirements requiring consideration and coordination for these areas; however, preliminary investigation indicates neither will be of significance here.
- Threatened and Endangered Species - As specifically required, investigations and coordination will be undertaken with federal (Dept. of Interior - Fish and Wildlife Service) and state agencies (Pennsylvania Game Commission, Fish Commission and PennDER) to identify the protected species and habitats that may be affected by the alternatives for the project.
- Prime and Unique Agricultural Lands - Summarization of analyses and coordination dealing with effects on the state's agricultural lands.
- Stream Modification and Wildlife Impacts - This section will fulfill mandated requirements to consult with U.S. Department of Interior - Fish and Wildlife Service and state agencies with regard to impoundments, diversions, channel changes and other modification of streams or bodies of water.
- Visual and Aesthetic Effects - This discussion will assess effects of the proposed action on visual and aesthetic qualities. Specifically, the view of the facilities as well as the view afforded from the system will be considered.
- Historic and Archeological Provisions - The EIS will clearly demonstrate compliance with requirements for historic and archeological preservation (36 CFR Part 800.4), including coordination and consultation with the State Historic Preservation Office, the Keeper of the National Register, and the Advisory Council on Historic Preservation.
- Construction Impacts - This section will be a summarization of those impacts which are associated with the construction of each proposed alternative, and will address the magnitudes of effect which can be anticipated when construction occurs within existing rights-of-way and when occurring on relocated rights-of-way; measures to minimize probable adverse effects will be particularly emphasized.

- List of Preparers - A list of those responsible for preparing the environmental document, background studies and the administrative and technical review of the document, including qualifications, expertise and experience.

- Mailing List - A list of entities to which the draft EIS is circulated for comment, and, in the final EIS, indication of entities that submitted comments.

- Comments and Coordination - The draft EIS will summarize the early coordination process including scoping; meetings with agencies, community groups and individuals; and the key issues and pertinent information received as a result of these efforts. The final EIS will include copies of all substantive comments received, along with a response to each. The final EIS also will contain a summary and disposition of substantive comments made of any public hearing or public involvement activity.

- Index - The index will catalog major subjects and areas of significant impact.

- Appendices - Material prepared in connection with the EIS, which is supportive of the information summarized and presented in the EIS, can be included as appendices, particularly material intended to substantiate analyses that are fundamental to the EIS, or material that is analytic and relevant to a decision to be made.

Preparation of the EIS and its related analyses represents a major effort to ensure the environmental acceptability of an HSR system. This document is part of an overall procedure to assure the widest possible dissemination and review, and a high level of outside participation in its preparation. Major elements of candidate processing procedures are outlined below:

- The early coordination and project scoping process would begin with the decision to implement an HSR system, which implies a need for environmental approvals.

- The initial action would be the preparation and publication of a notice of intent to undertake the project and prepare the environmental impact statement. This notice will be published in the Federal Register, the Pennsylvania Bulletin, and in local newspapers throughout the state. In addition to the formal notice to be placed in legal sections of newspapers, display advertisements should also be included to widen public awareness of the studies. These notices should include a description of the proposed action and its need and purpose and a map depicting the study area. The notices and advertisements should also identify a person within the lead agency to be contacted for further information. These notices should also explain the means by which the public and agency involvement is carried out.

- In conjunction with publication of notices of intent, an early coordination letter would be sent to all federal, state and local agencies, public officials, organizations and individuals that may be affected. The intent is to solicit agencies' and officials' participation and to provide them an opportunity to identify issues of greatest concern. This letter would explain the proposed project and its purpose and need. Maps and other graphics should accompany this letter, as should a plan of study. Environmental categories of obvious concern will be identified and the methodologies and procedures proposed for their analysis would be outlined.

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3 Edward J. Ward, "Noise in Ground Transportation Systems," High Speed Ground Transportation Journal, Vol. 7, No. 3, 1973, page 298.

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CHAPTER 16
ECONOMIC PERFORMANCE OF HSR SERVICES IN FRANCE AND JAPAN

The service that best represents American HSR experience is Amtrak's Northeast Corridor, with average speeds on New York-Washington runs of 34 mph and top speeds of 120 mph. It is necessary to look abroad to find examples of true HSR service, with average speeds of 100 mph or greater. Two such services are examined in this chapter, and an attempt is made to compare and contrast the underlying conditions in these markets, both with each other and with existing U.S. and Pennsylvania corridors.

There are two premier HSR services in the world today: the Shinkansen of the Japanese National Railways (JNR) and the TGV of the French National Railways (SNCF).[1] In both services, maximum speeds are 125 mph or higher. The fastest are the TGV trains that entered service in 1982 on the LGV (Ligne a Grande Vitesse) between Paris and Lyon, and which achieve speeds of up to 168 mph. JNR has 1147 miles of Shinkansen offering high-speed services, and SNCF operates the TGV on 1189 miles of line. While the French trains are now the fastest, the Japanese service is of considerably longer duration, with 125 mph train service having begun in 1964 on the New Tokaido Line between Tokyo and Osaka.

JNR's Shinkansen and SNCF's LGV and TGV— while exceeding speeds of trains anywhere else in the world—differ in the nature and extent of their services. JNR's great success on its first Shinkansen —The New Tokaido Line—has led to extension of new roadbed through quite a bit of Japan. The initial and continuing overwhelming financial success of the New Tokaido Line has not, however, been replicated on the newer lines, as is discussed below.

To date, SNCF has built a total of 260 miles of new line, although it operates the TGV over 930 miles of existing line, and has plans to build 427 miles of new line southwest of Paris (TGV-Atlantique). On existing lines, SNCF operates a conventional mix of train services—both freight and passenger. On new lines, both JNR and SNCF operate passenger trains only.

SNCF operates TGVs between Paris and Lyon; Paris and Lausanne and Geneva, in Switzerland; and Paris and Annecy, Chambery, Grenoble, Marseille, Montpelier, St. Etienne, and Lyon-Perrache in the Southeast of France. The trains between Paris and Lyon run on new line for most of the distance and there attain their highest speeds—up to 168 mph. Off the new line, the TGVs run at speeds of up to 110 mph. The TGVs have been in operation for approximately 2.5 years of which two years have been on the new line; this operation so far is a great financial success. This encouraged SNCF and the French government to consider and act favorably on the construction of new high-speed lines to LeMans and Tours.

This chapter reviews the experience of JNR and SNCF in building and operating HSR systems, with particular emphasis on the fundamental relationships between revenues and economic costs. Each system is examined separately, then comparisons are made between the systems and with Pennsylvania Corridor conditions.

16.1 THE SHINKANSEN

The New Tokaido Line between Tokyo and Osaka was placed into commercial service in 1964, using the best rail technology of the time. Since its inception the fast through trains on that line have made the 322-mile run in 3 hours and 10 minutes at an average speed of just over 101 mph.

Following the enormous financial and popular success of the New Tokaido Line, the Shinkansen was extended from Osaka to Hakata on the western island of Kyushu. Service on this new Sanyo Line was opened 100 miles to Okayama in 1972 and 245 more miles to Hakata in 1975. The Hikari (express trains) run over the Sanyo Line in 3 hours and 28 minutes at an average speed of 100 mph. Trains run the full distance of 668 miles between Tokyo and Hakata in 6 hours and 40 minutes at an average speed of 100 miles per hour.[2]

The Sanyo Line has not been nearly so great a financial success as the Tokaido Line for reasons discussed below. Nevertheless, with the financial support and encouragement of the Japanese government, JNR in 1982 built and completed two more Shinkansen to the northeast of Tokyo. The Joetsu Shinkansen lies between Omiya (just north of Tokyo) to Niigata on the north coast of Honshu. The fast trains there make the 168-mile run in 1 hour and 45 minutes, for an average speed of 96 mph.[3]

The Tohoku Shinkansen extends 291 miles from Omiya to Morioka near the northern end of Honshu. The fast trains make the run in 3 hours and 17 minutes at an average speed of 89 mph.[4]

Construction is under way to complete the Joetsu and Tohoku Shinkansen to Tokyo. Until this link is completed, these lines operate at a disadvantage, their terminal being 20 minutes away from central Tokyo. A line is also being constructed between Tokyo and Tokyo's International Airport at Narita, to be known as the Narita Shinkansen. Five other Shinkansen lines have been planned but construction has been deferred for the time being.[5]

16.1.1 Behind the Shinkansen

It is interesting to note that the early justification for the New Tokaido Line lay in the inadequacy of the existing narrow-gauge Tokaido Line to handle then-current levels of passenger traffic. JNR and Japanese government officials at the time determined that demand greatly exceeded capacity and could best be handled by the building of a new line to be operated at speeds calculated to achieve high utilization of equipment. Any estimates of patronage based on growth in traffic, patronage diverted from other modes, and induced patronage would be, in effect, "frosting on the cake". As a result, little risk was associated with the accuracy of the demand forecasts. That significant demand for HSR services on the New Tokaido Line existed is revealed by the fact that, almost from the beginning, it has had operating ratios (expenses/revenues) below 50 percent.[6]

The newer Shinkansen lines were constructed to serve a social purpose as well as to meet transport demand. In the 1970s, the Japanese government found that economic growth had brought overcrowding and "imbalances in society" and that dispersal to more rural regions would be desirable.[7] The Shinkansen would "accelerate this trend of growth, and so . . . greatly help the orderly development of the entire nation".[8] Again, no careful determinations of demand were needed; the lines would be built regardless of the forecasts. The financial success, or lack of success, of the new lines reflects the lower level of patronage demand in prospect at the time the lines were planned and built. More specifically, the Tokaido Line has averaged 350,000 passengers per day over 18 years. The Tohoku Line handled 49,000 passengers per day in its first year of operation, and the Joetsu Line is expected to carry 35,000 passengers per day.[9]

It is much too early to discern whether the building of Shinkansen into less densely populated regions of Japan has encouraged population dispersal and economic growth. One official in the Japanese government has asserted that the growth rate of cities on the Shinkansen Lines has been greater than comparable cities off line.[10] Determining whether this can be attributed to the Shinkansen awaits more thorough verification.

Clearly, population levels in a rail corridor are related to volumes of patronage. It may be interesting to note the population of the major cities in each of the Shinkansen corridors:

Shinkansen Corridor	Major Cities' Population
Tokaido	13,998,000
Sanyo	8,464,000
Tohoku	2,175,000
Joetsu	1,033,000

On a per-mile basis, the figures change but the rank is retained:

Shinkansen Corridor	Major Cities' Population per Mile of Line
Tokaido	59,000
Sanyo	24,533
Tohoku	7,474
Joetsu	6,148

The evidence is nearly indisputable that in Japan, the higher the population of cities on line, the better will be the financial results of the operation. Whether societal benefits eventually will overweigh economic costs remains unknown. JNR and the Japanese government have, however, implicitly concluded that HSR is a worthy investment as a tool for regional development.

16.1.2 Financial Results of the Shinkansen

Overall, Shinkansen operations are immensely profitable. In Fiscal 1982, (year ended March 31, 1983), revenues were 921 billion yen and expenses were calculated to be 718 billion yen, yielding an operating ratio of 78 percent. As noted above, however, there are wide disparities in financial viability over the system. The Tokaido Line is far and away the most profitable; the Sanyo Line is marginal and the other two Shinkansen currently show deficits.

The financial performance of the Shinkansen groups is shown in Table 16-1. It is impossible, short of an audit, to ascertain how financial data for the Shinkansen are arrived at. There are many possibilities for variance -- especially on the expense side. For example, depreciation and amortization may be either stretched out or concentrated in the early years of life. Capital expenditures may not in other ways be fully accounted for. We do know that the Japanese Railway Construction Company, which builds the Shinkansen, is required to pay competitive interest rates on construction funds it borrows from the Japanese government. Presumably, then, there is no capital cost subsidy extended to JNR. The term for amortization of capital is, however, another question, just as it often is in the United States.

We also do not know the terms on which JNR has obtained the land for rights-of-way. If market value was the criterion, then the cost of land would, according to U.S. accounting standards, be accurately valued.

16.2 HSR SERVICE IN FRANCE

SNCF has evidenced interest in fast passenger trains for many years. It tested an electrically propelled trainset at 205 mph as early as 1956. In more recent years it has operated the fastest commercial trains in Western Europe. Geography, economics and cultural dispositions perhaps account for SNCF's role in the vanguard of high-speed rail passenger service developments. Today its TGV offers the fastest passenger-train service in the world.

16.2.1 Behind the TGV and LGV

The original motivation or justification for developing the TGV and building the LGV lay in the capacity constraints on the existing line between Paris and the southeast of France. Just north of Dijon the old double-track line runs through a mountain cut, which had become a severe bottleneck. Because of the terrain, the cost of expanding its capacity threatened to be enormous.

SNCF began to consider the feasibility of building a completely new line between Paris and Lyon (Lyon is south of Dijon). The decision was made that freight traffic should stay on the existing line, and that the new line should be exclusively for passenger service. This meant that civil engineering standards for the line would be free of the constraints normally applied to a multi-purpose rail line. Grades, for example, could range up to 3.5 percent in contrast to the usual 1 to 2 percent maximum.

SNCF decided in the late 1960s and early 1970s to proceed with testing, principally of rolling stock. The French government, which owns 51 percent of SNCF, insisted on a rigorous economic evaluation of the feasibility of the new line. This evaluation continued through 1974, when the government approved SNCF's plans.[12]

In the evaluation, SNCF determined that the LGV and TGV could produce sizable net returns and that the social return (collectivité) would be more than 20 percent. This substantial social return was based on savings in travel time and took

TABLE 16-1

FINANCIAL RESULTS OF THE SHINKANSEN[11]
Fiscal Year 1982

	Tokaido/Sanyo	Tohoku/Joetsu	All Shinkansen
Revenues*	816.2	104.5	920.7
Expenses*	450.4	267.2	717.6
Net Income (Deficit)*	365.8	(162.7)	203.1
Revenue Passengers, millions	124.8	18.1	
Revenue Passengers/ Mile of Line	186,826	39,434	
Operating Ratio	55%	256%	78%

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* billion Yen

into consideration the interaction between rail passenger service and other modes--air and automobile. Since intercity bus transportation by any entity other than SNCF is prohibited in France, the new line would not be threatened from that source of competition. Furthermore, as a matter of policy, air fares on the French national domestic airline (Air Inter) are kept high, and as a result non-business travelers rarely use air services. With those conditions, the proposed new lines and services showed substantial promise.

Construction on the new Paris-Lyon line was begun in 1976 and enough of it was completed by 1981 that service could begin. Land for the right-of-way, acquired at market prices, according to SNCF officials, has amounted to about 10 percent of the capital costs of the line. Financing was approved by the French government, but funds were acquired in private markets (both domestic and foreign) as a part of SNCF's overall capital budget. It appears that SNCF, although it may operate in a somewhat protected market, did not receive capital subsidy for construction of its new line and development of new rolling stock. SNCF reports, however, that in 1982 it paid about $35,000 in taxes on 185 miles of the new line. This amounts to about $200 per mile per year--not a high figure. However, taxes on 46 trainsets were $2.4 million or about $50,000 per trainset per year.[13]

SNCF carried out what appears to have been a comprehensive set of surveys in order to forecast patronage of the new services. On-board surveys were made on the conventional trains over a period of time. In addition, SNCF piggybacked on household surveys made regularly by the Central Statistical Bureau of the French government.[14]

After TGV services had begun, SNCF found that an unexpectedly large proportion of patronage on the new trains came from induced travel. Induced travel is difficult to measure. If a traveler makes a trip that he otherwise would not have made, it can be said that he has been induced by the new service. However, trips made after the first trip may or may not be induced, i.e., once having made a trip a traveler may repeat regardless of whether the new service is available. Also, of course, some travelers use the new service as a novelty with little prospect of repeating.

By taking on-board surveys, SNCF has attempted to obtain passenger profiles. The most important question in the surveys, insofar as induced traffic is concerned, is: "If the TGV did not exist, what would you have done?" Assuming honest responses, this probably provides a fair measure of induced traffic. The surveys also ask for the number of times the trip has been made in the past 12 months. Over time the presumed decrease in "none" answers to this item will account for the novelty effect, assuming that induced travel which contributes to long-term steady growth in patronage should not be one-time-only travel.

16.2.2 Financial Results of the TGV-Southeast

Based on price levels prevailing in June 1984 and an exchange rate of eight francs to the dollar, the cost of the new line has been $3.75 million per mile for 260 miles. Based on June 1984 prices the average cost per trainset has been $6.6 million.[15] (Each trainset has 287 first-class seats or 111 first-class seats and 275 second-class seats.)

The TGVs in conjunction with the LGV are expected to produce satisfactory financial results over the life of the project; estimates are 15.2 percent project return and 25 to 30 percent on the net social investment cost of the new line and the rolling stock. These would obviously be very gratifying results for SNCF. In Fiscal Years 1982 and 1983, the TGV-Southeast turned up negative figures after operating and capital expenses. In Fiscal Year 1984, the net result was positive and the cumulative result became positive, as shown in Table 16-2.

TABLE 16-2

FINANCIAL RESULTS — TGV-SOUTHEAST
(Exchange rate, 8FF/$)
FYs ended December
Dollar Amounts in Millions

	1982	1983	1984
Operating Revenues, Total	146	244	381
Direct Operating Costs	64	106	145
Infrastructure Amortization	18	21	27
Equipment Depreciation	12.2	20	25.5
Operating Expenses, Total	94.2	147.0	197.5
Income*	51.8	97.0	133.5
Operating Ratio*	65%	60%	52%
Return on Investment*,+	3.2%	6.0%	11.4%
Financial Charges	81.7	100.0	136.5
Net Income	(29.9)	(3.0)	47.0
Cumulative Net Income	(29.9)	(32.9)	14.1

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* before financial charges

+ gross investment = $1.612 billion

16.2.3 Demography, Traffic and Fares

Demography

The Paris-Southeast TGV serves a population in Greater Paris of about 10 million persons and a population in southeast France of about 15 million.[16] This sum, 25 million, is relatively small compared to the 60 million population in the Tokyo-Osaka Corridor and 33 million in the Northeast Corridor of the United States Rail passengers before the start of TGV service amounted to about 14 million passengers per year. While the rail share of total traffic, about 39 percent, is high for countries with high auto ownership, rail ridership per 100 population is not high in comparison to Japan, even using SNCF's forecast of 22 million rail passengers for 1985.[17] For the Paris-Southeast rail services, even with the increases brought by the TGV, the proportion of rail passengers to corridor population is less than one.[18] By contrast, rail ridership in the Tokyo-Osaka Corridor is nearly double the population.

Traffic

SNCF believes that the TGV and the new line will lead to increased rail traffic and increases in the rail share of total traffic in the Paris-Southeast market. Past and projected traffic, with and without the TGV, is shown in Table 16-3.

TABLE 16-3

TRAFFIC FORECASTS BY TRANSPORT MODE WITH AND WITHOUT TGV[19]
(Millions of Passengers/Year; Percent Market Share)

PARIS-SOUTHEAST AXIS

					1985 forecast			
	1969 results		1979 results		Without TGV		With TGV	
Auto	7.2	37.5%	16.8	48.0%	21.6	48.0%	18.8	41.0%
Air	2.0	10.4%	4.6	13.1%	7.3	16.2%	5.1	11.1%
Rail	10.0	52.1%	13.6	38.9%	16.1	35.8%	22.0	47.9%
Total	19.2	100.0%	35.0	100.0%	45.0	100.0%	45.9	100.0%

PARIS-LYON (Origin-Destination)

			1985 forecast			
	1979 results		Without TGV		With TGV	
Auto	1.46	42%	1.74	39%	1.08	23%
Air	0.84	22%	1.32	29%	0.36	8%
Rail	1.28	36%	1.43	32%	3.26	69%
Total	3.58	100%	4.49	100%	4.70	100%

It is notable that rail would be on a downward trend without the advent of the TGVs They are expected to add over 12 percentage points to the rail market share. Nearly 60 percent of the rail increases will come from a decline in auto ridership.

Fares

Attempting to translate fares quoted in French francs to dollars is somewhat dubious because of uncertainty that the relative purchasing power of the franc and dollar matches the exchange rate. At the current exchange rate of about eight francs to the dollar, the first-class fare on the TGV between Paris and Lyon is $34.13, or 13 cents per mile. The second-class fare is $23.13, or nine cents per mile. In contrast, the air coach fares are $55.13, or 21 cents per passenger-mile. The out-of-pocket running cost for autos is estimated by SNCF to be about $43.75, or 17 cents per mile. Thus the coach fare of nine cents per passenger-mile must be an important attraction to low- and middle-income people.[20]

16.2.4 Beyond Paris-Southeast

Beginning in September 1981, SNCF and the French government have planned to build a new high-speed line southwest from Paris. This proposed new passenger-only line, TGV-Atlantique, would run from Paris in a southwesterly direction 159 miles to Courtalain. Thence it would split into two segments: the West branch would go 128 miles to LeMans while the Southwest branch would go 140 miles to Tours. Altogether, the new high-speed line would extend for 427 miles and would carry heavy traffic flows from the Paris region toward Brittany on the West branch and toward Bordeaux on the Southwest branch.

According to SNCF, the TGV-Atlantique project would render unnecessary very large additional investments in the conventional lines. The cost of the new line will be 7.6 billion francs, and the new rolling stock 4.4 billion francs (in 1982 terms). The new line will obviate an investment of 6.9 billion francs on old lines, so the net investment cost of the new line is calculated to be 5.1 billion francs.

The new line is expected to provide a return of 12.9 percent on investment. The expected net social return will be 23.6 percent, largely realized through large savings in journey time.[21]

16.2.5 The French Experience

Overall, SNCF has been extraordinarily successful in operating high-speed trains. Even before the LGV and TGV, SNCF was running at 100-plus mph with reasonably satisfactory financial results on certain routes such as Paris-Bordeaux. The TGV-Southeast has been financially and socially very successful and the TGV-Atlantique promises to be profitable also. This financial success cannot be attributed to very high population densities, as in Japan, on the New Tokaido Line. Population densities in the French corridors are relatively low. Apart from SNCF's obviously high proficiency and productivity in rail operations, the answer must come from the relatively high use of rail by travelers in France. This can be attributed to (1) the absence of intercity bus service, (2) the relatively high internal air fares, and (3) the high taxes on gasoline for consumption on the highways. Together, these circumstances put rail in a strong market position. The SNCF has moved effectively to exploit its opportunities, and has gotten strong support from the French national government.

16.3 CONCLUSIONS

Both the Japanese high-speed services on the New Tokaido Line and the French TGV on the LGV have been successful both commercially and technically. Each of them has high load factors and low operating ratios. Both have been in the vanguard of state-of-the-art operation of trains at high speeds. JNR has not had an accident involving a fatality to passengers in the 20 years of operation of the New Tokaido Line. So far, the TGVs have operated without accident. It is fair to say that the TGV and New Tokaido Line high-speed passenger services have met all expectations.

Neither system, Japanese or French, seems to owe its success to any kind of explicit or hidden financial subsidy from its government. Both pay capital charges and taxes, and appear to have acquired property at market prices.

To what can the success of the French and Japanese high-speed services be attributed? The answers offer an interesting contrast:

A population density of more than 2,000 persons per square mile between Tokyo and Osaka, combined with relatively low automobile ownership in Japan, has produced a very heavy demand for short haul (less than 300 miles) passenger transport. Intuitively, one would believe that high-capacity transportation systems would seem to be more successful in regions of high population density. This proposition is confirmed in Japan by the relatively poor financial performance of lines in less populated regions. In Japan, high population density and successful high-speed passenger train services seem to go hand in hand.

In France, the case seems to be different. France is the least densely populated major country in Western Europe (except the Scandinavian countries). The new line (LGV) traverses a region of relatively low population density. In addition, France has high per-capita auto ownership. Neither population density nor auto ownership in France favors rail passenger service.

On the other hand, the French government prohibits intercity bus operation and as a matter of policy requires the national airline to maintain high fares. Both favor rail passenger service. An added factor almost certainly is that SNCF has emphasized and improved passenger services, while services in other countries have declined. French travelers are accustomed to good, reliable and fast passenger train services. Presumably, the results of all these conditions are that the French tend to turn to trains when they travel.

How do conditions in France and Japan compare with those of the Philadelphia-Pittsburgh corridor? Population density in Japan in the New Tokaido corridor is many times greater than that in Pennsylvania corridor. Paris-Lyon-Southeast's population per square mile is in somewhat higher than that in Pennsylvania. Population density is not a positive factor in the Philadelphia-Pittsburgh corridor relative to France or Japan. On the other hand, the Philadelphia-Pittsburgh line may be able to serve large volumes of passengers originating and/or terminating beyond the endpoints. Some two-thirds of all the passengers on the French TGVs originate or terminate South or East of Lyon.

It has generally been agreed by analysts that demand for passenger transportation is income-elastic, i.e., as personal incomes rise, consumption increases disproportionately. A region with a high proportion of high-income receivers is likely to have a higher-than-average demand for passenger transportation. Pennsylvania family incomes rose 70 percent in constant dollars between 1960 and 1982. This is a positive factor for passenger transportation demand. On the other hand, less than 41 percent of Pennsylvania households in 1980 were above median family income for the U.S.

It would appear that the competitive conditions in the Philadelphia-Pittsburgh corridor may be less favorable than they are in the Tokaido and Paris-Southeast corridors. There are no arbitrary constraints on intercity bus operation in Pennsylvania, and air services are now intensely competitive, although short-haul air is priced substantially higher than either existing or proposed rail. Auto ownership in Pennsylvania is more than 50 per 100 of population, a figure significantly higher than in Japan—about 20 per 100 of population—and somewhat higher than France, which has fewer than 35 per 100 of population. Finally, rail passenger service may suffer a status or image problem with the American public, unlike France or Japan, which HSR would have to overcome.

Table 16-4 summarizes some of the relative conditions among the foreign corridors, the Northeast Corridor, and the Pennsylvania Corridor with respect to demographics and transport choice.[22]

While the factors discussed in this chapter are of great interest to students of transportation systems, operations, and business, and equally of interest to decisionmakers in Pennsylvania, there is no possible direct application of the results obtained abroad to any specific U.S. corridor.

TABLE 16-4

COMPARATIVE DEMOGRAPHIC AND TRAVEL DATA FROM FOUR CORRIDORS[22]

	CORRIDOR			
	NTL	**Paris-Southeast**	**NEC**	**Pennsylvania**
Route	Tokyo-Osaka	Paris-Lyon+ Southeast France	Boston-Washington	Philadelphia-Pittsburgh
Population, millions	67.4	25.0	32.6	10.0
Population Density, persons/sq mi	2582	500	700	375
Rail Passengers, millions, 1983	107.5	15.4	11.0	1.1
Rail Passengers/yr/ 100 population	187	62	34	11
Auto Ownership/ 100 population	22	33	50	51
Through Buses/day	not significant	0	133	18
Ratio, $\frac{\text{Air Fare}}{\text{Rail Fare}}$	1.2	3.7	1.9	3.4

References

1 "Shinkansen" means "new wide-gauge line(s)" in Japanese. The trains which operate on the Shinkansen network are known as "Bullet Trains" and are sometimes referred to loosely as Shinkansen.
"TGV" stands for "Tres Grand Vitesse" or very-high-speed train. The newly constructed portion of railroad on which the TGV operates in part is known as the "LGV" for "Ligne a Grand Vitesse" or high-speed line.

2 Robert A. Nelson, High Speed Rail Passenger Transportation in Six Countries and the Northeast Corridor of the United States, a report to the Federal Railroad Administration, Washington, 1978.

3 Japanese National Railways, International Department, Maurinouchi, Tokyo, March 1983.

4 Ibid.

5 Ibid.

6 Op. cit., Nelson

7 Basic Direction of a Comprehensive Transport Policy based on Long Term Perspectives, Transport Policy Council, July 6, 1981.

8 Op. cit., Japanese National Railways

9 Op. cit., Japanese National Railways.

10 In a talk to the conference on High Speed Ground Transportation held in Arlington, Va., in November 1983 under the auspices of the Transportation Research Forum.

11 Data is not available at present to separate the four Shinkansen lines. Data is shown for FY 82, the latest year for which Tohoku/Joetsu results have been provided. Data from Japanese National Railways, Washington, 1984.

12 Robert A. Nelson, data from consulting assignment with French government, 1973.

13 Letter from Mr. Hubert Autruffe, Technical Director of Sofrerail, Paris, 3/15/84.

14 Ibid.

15 Claude Berlioz and Michel LeBouef, "Economic Balance Sheet of the TGV -Sud-Est", French Railway Review, Vol. 1, No. 4, 1983, pp. 308ff.

16 Ibid., page 310.

17 Op. cit., Nelson.

18 French National Railroads, New South East Line TGV First Years Operation: Results Appraisal, February 1983, Annex 6.

19 Ibid.

20 Op. cit., French National Railroads.

21 E. Chambrou and M. LeBouef, "The TGV Atlantique", French Railway Review, Vol. 1, No. 4, 1983, pp. 371 ff.

22 Data in Table 16-4 are not always for comparable years, and are in some cases estimated values. The data is intended to indicate the divergence in local conditions and to provide general trends only.

CHAPTER 17
EVALUATION OF ALTERNATIVES

The prior 16 chapters of this report have addressed the Pennsylvania High Speed Rail feasibility study from a number of diverse vantage points. It is the purpose of this chapter to place all the key data developed in this study into a perspective from which informed decision making can take place.

The benefits which an HSR system could effect in Pennsylvania accrue to three groups of persons: users of the service, non-users of the service with a public- sector orientation, and non-users with a private-sector orientation. These groups correspond, broadly speaking, to system users, system sponsors and system investors. In reality, a given individual may share in all of these effects. A system user is also benefitted through economic growth in Pennsylvania which an HSR system would provide, and such a user may also be an investor in the system.

17.1 TRANSPORTATION BENEFITS

The primary benefits received by system users are the transportation benefits: reduced trip time, new scheduled arrival and departure times, and additional service and amenities over today's options. While by no means the only transportation benefit, the most fundamental of these is trip time reduction. As would be expected, larger reductions in trip time require higher initial capital investments. For the alternatives considered in this preliminary feasibility study, Figure 17-1 shows the relationships between estimated trip time and average speed on the one hand, and estimated capital cost on the other. In this Figure, Alternative A (which is the do-nothing alternative) is plotted at the existing calculated trip time and zero cost. Alternative B, for which no detailed cost estimate was developed, is plotted at an estimated cost of $500 million for purposes of comparison. Alternatives C, D and E are plotted using the values developed in Chapters 5 and 8.

The improved transportation service provided by Alternatives C, D and E is projected to attract an increasing number of riders, as discussed in Chapter 9. Figure 17-2 shows the base-demand and high-demand ridership projections as a function of estimated system costs. From the average trip length and trip time savings data discussed above and in Chapter 9, the total amount of aggregate time savings can be calculated. These values, which are in units of millions of passenger-minutes saved per year, are also plotted in Figure 17-2 for Alternatives C, D and E. Aggregate time savings rise faster than ridership because of the improved travel times of the more costly alternatives.

To gain some insight into the aggregate value of the transportation benefits, two estimates of the value of time savings were made. In Case A, using market segmentation data from Chapter 9, business and commuter travelers were grouped together, constituting 55 percent of the market. The remaining 45 percent consists of the tourist and other categories. Assuming that the business/commuter travelers value their time at twice their income, and that their average income is $40,000/year; and that the tourist/other travelers value their time at the same rate as their income, and have average income of $21,000/year; then the weighted average value of saving 1 hour of time is approximately $25.70.

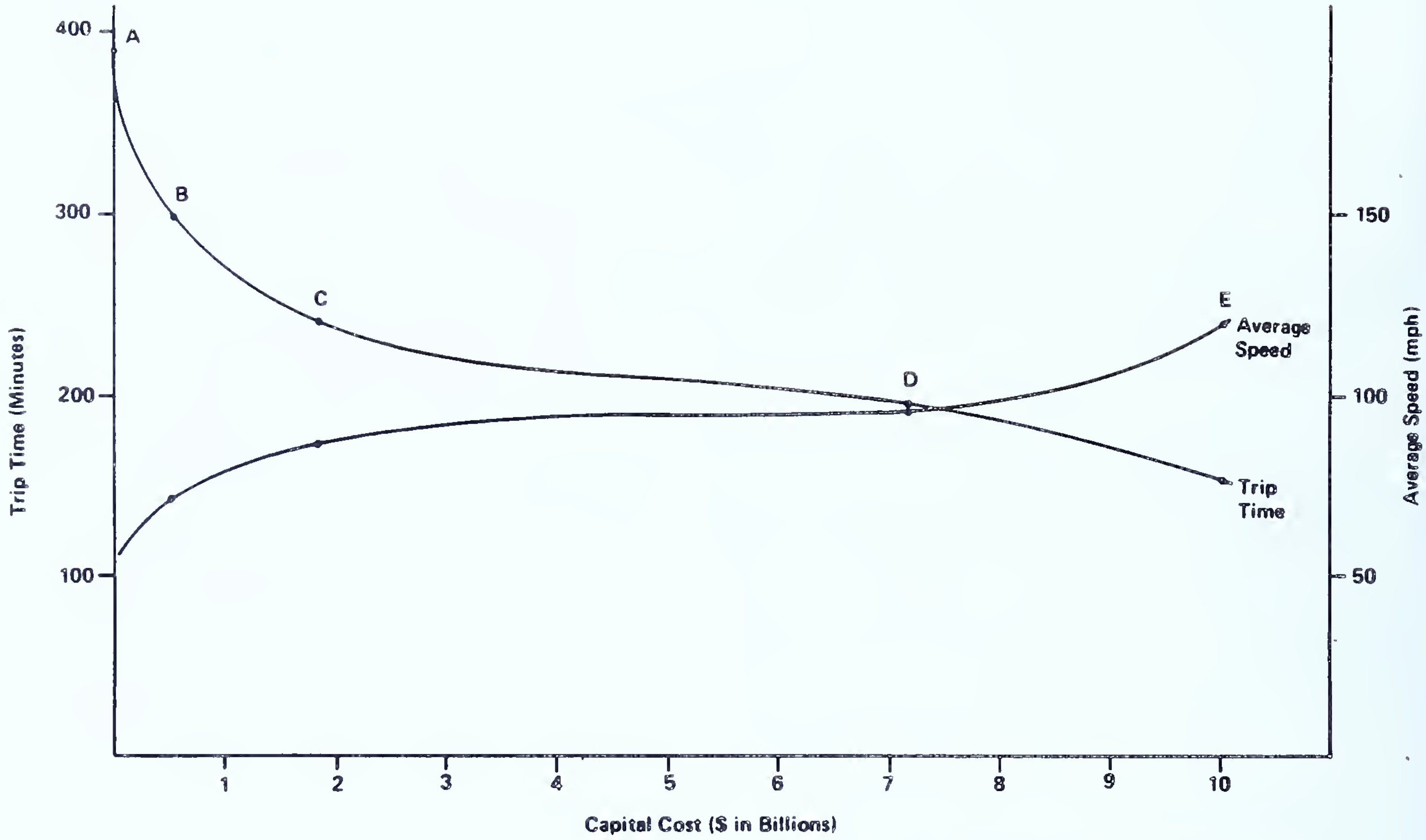

Figure 17-1
Average Speed and Trip Time vs Capital Cost, by Alternative

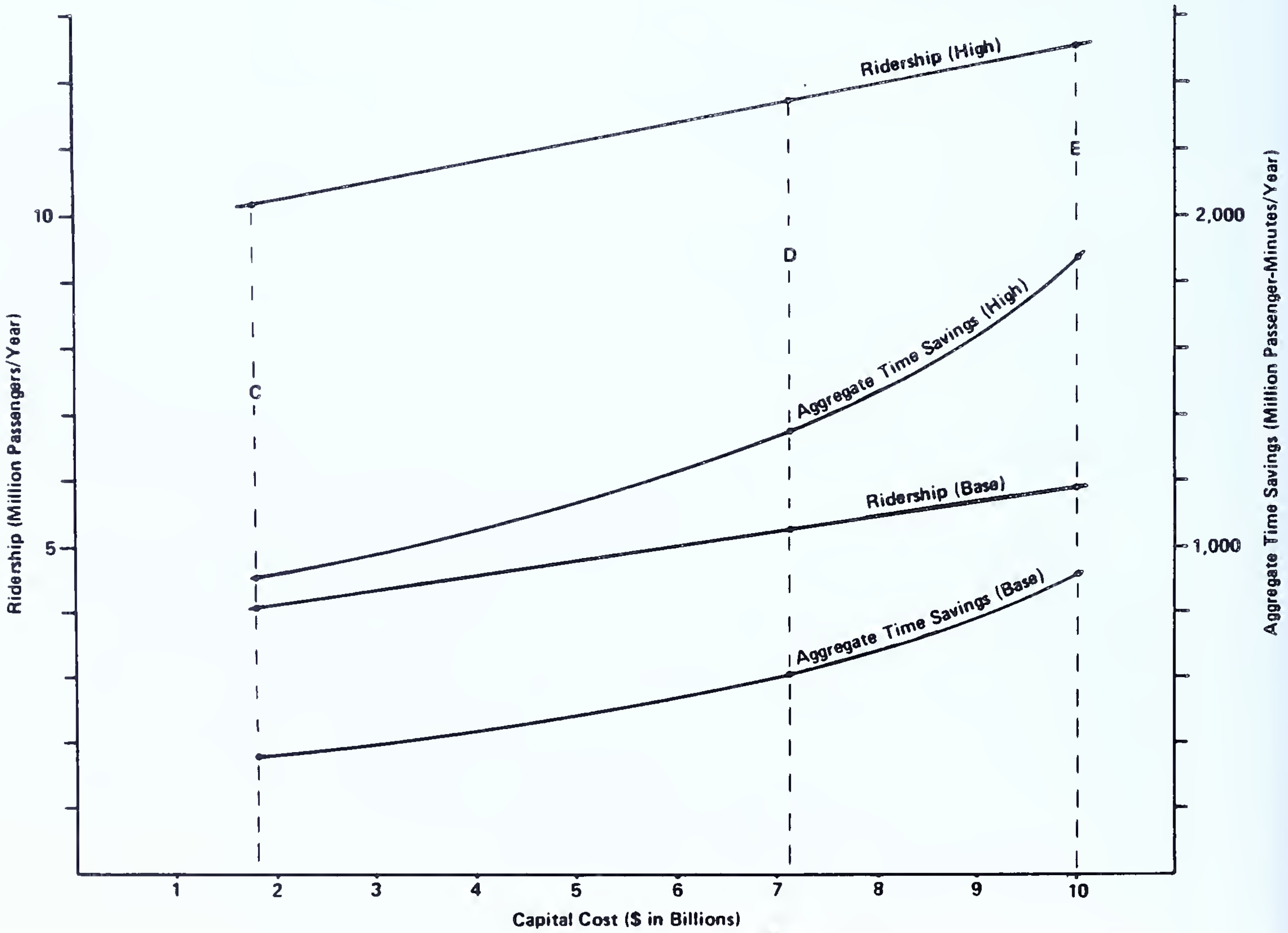

Figure 17-2
Ridership and Aggregate Time Savings vs Capital Cost, by Alternative

In Case B, commuters were grouped with tourist/other, thereby accounting for 70 percent of the market, with business travelers making up the remaining 30 percent. Assuming that all travelers value their time equal to their effective hourly wage rate, and that the average annual income of business travelers is $35,000, and for the remaining group is $21,000, then the weighted average value of saving 1 hour of time is approximately $8.20.

Using the aggregate time savings and value of time data described above, a "payback period" was calculated which represents the number of years of annual monetized time savings required to return the capital cost of each alternative. These periods, which do not reflect ridership growth and are not discounted, are shown in Table 17-1.

At this stage of the feasibility study, no data exist to determine whether Case A or Case B would be more applicable to Pennsylvania travelers, or if either case properly reflects traveler behavior.

17.2 ECONOMIC BENEFITS

Beyond the transportation benefits, HSR would bring very significant economic benefits to Pennsylvania, both during the construction period and lasting throughout the operating phase.

As described in detail in Chapter 14, the economic benefit indicators used in this study are: employment increases, personal income increases, gross state product increases, and state tax revenue increases. Each of these indicators is directly influenced by the amount of money spent in the construction or operations of an HSR system. Figure 17-3 shows the state tax revenue derived from the HSR project over the entire construction period, as well as the increase in the growth rate of state tax revenues over the same period. The growth rate curve is distorted by the uneven construction period of Alternatives C, D and E (8, 10, and 12 years, respectively). Data for the other economic indicators (Table 14-1) have similar plots, not shown here. The curves for tax revenues plotted in this chapter can be considered proxies for overall economic impact.

A significant observation from Figure 17-3 is that the state government would have additional financial resources which could be used to assist in the financing of an HSR system, stemming solely from the existing tax structure.

Figure 17-4 shows the trend of the economic performance indicators during the operating period, again using state tax revenues for illustration. Note that while a continuing revenue stream exists during the operating period, it is not influenced greatly by the level of the system. Any of the HSR alternatives produces significant increases in the growth rates of any of the economic indicators studied.

17.3 RELATIVE BENEFITS OF ALTERNATIVES

Figures 17-2 through 17-4 all show curves sloping upward to the right, indicating that increased capital cost results in better performance, whether such performance be measured by ridership, trip time savings, or economic impact. A clearer picture of the relative performance of Alternatives C, D and E in achieving these benefits and

TABLE 17-1

TRANSPORTATION BENEFIT

ALTERNATIVE	Demand	PAYBACK PERIOD, YEARS Case A	 Case B
C	Base	11.6	36.4
D	Base	27.3	85.7
E	Base	25.6	80.5
C	High	4.8	15.1
D	High	12.4	39.0
E	High	12.4	38.9

TABLE 17-2

COST-BASED PERFORMANCE INDICATORS

ALTERNATIVE	Millions Passenger Minutes Saved/Billion $ Capital Cost	Normalized Time Savings/$	Public Sector IRR, Percent	Normalized IRR
Base Demand				
C	200.2	1.0	4.7	1
D	85.2	.43	1.0	.21
E	90.7	.45	0.5	.11
High Demand				
C	483.0	1.0	14.7	1
D	187.1	.39	7.1	.48
E	187.3	.39	6.2	.42

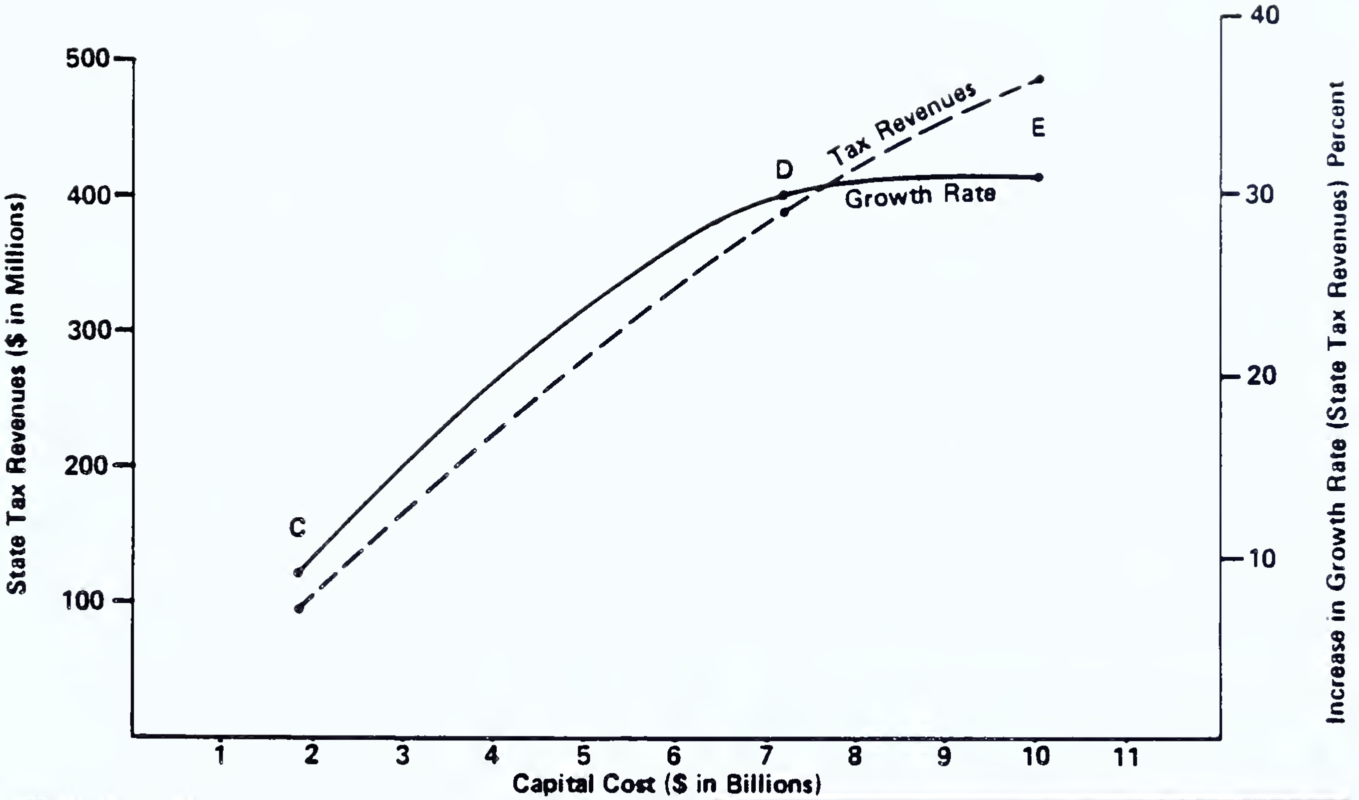

Figure 17-3

State Tax Revenue and Growth Rate Increase by Alternative—Construction Period

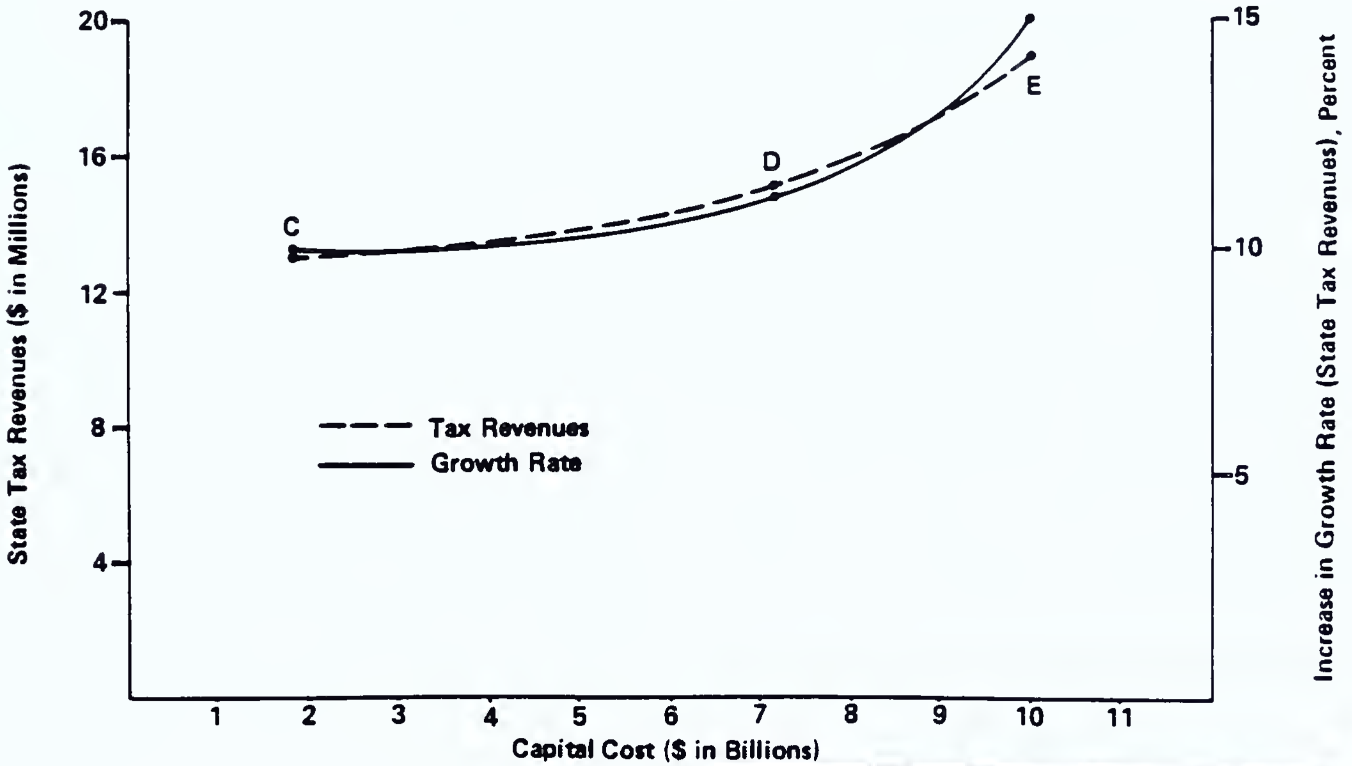

Figure 17-4

State Tax Revenue and Growth Rate Increase by Alternative—Operating Period

the costs associated therewith can be obtained by "normalizing" the data; that is, dividing all data points by the highest-valued point. Normalized data ranges from zero to one or 0 to 100 percent.

Figure 17-5 condenses the plots of Figures 17-2 through 17-4 on a normalized basis, with the Alternative E values at 100 percent, for the base demand case. High-demand ridership is also included in the figure; the other variables do not shift as significantly. In addition, normalized capital cost is plotted in Figure 17-5 as an index identical to the variable on the horizontal axis. In examining data in Figure 17-5, a curve which is beneath the cost line represents a variable which falls more sharply than capital cost falls (in descending from Alternative E to D to C), and any curve above the cost line represents a variable that falls less sharply than does capital cost.

Note that economic impact (state tax revenues in this case) falls virtually identically with cost, and economic growth rate falls only slightly less sharply. Aggregate time savings and trip time fall substantially less sharply than capital cost, and ridership falls even less sharply. This behavior, which is a fairly typical result in studies of this type, is a consequence of the declining trip-time versus construction cost curve. Each additional minute of time savings results in an additional construction greater than that of the prior minute. This concept suggests looking at the transportation benefits on a per-unit-cost basis: that is, passenger-minutes saved per dollar invested (capital cost). This figure of merit is highest for Alternative C, as shown in Table 17-2. The normalized data is shown in Figure 17-6, as "time savings/$."

The time savings/$ curve in Figure 17-6 suggests that Alternative C is the superior alternative from the standpoint of producing transportation benefits most efficiently, although Alternatives D and E produce more total benefit. All alternatives are seen to be approximately equal in their efficiency of generating economic benefits.

An additional evaluation which is essential from the investor perspective is that of project return, as discussed in Chapter 11. Table 17-2 also shows the internal rates of return for the three alternatives (public sector perspective) and their normalized values for both the base- and high-demand scenarios, which are plotted in Figure 17-6 as "IRR". The IRR curves have the same trend as the time savings/$ curves, and indicate that Alternative C has the highest project return, with investment returns for Alternatives D and E falling sharply.

Evaluating Figures 17-5 and 17-6 poses a dilemma. To maximize the benefits of improved transportation and economic performance, Figure 17-5 would suggest Alternative D or E as the most useful alternative. To maximize the efficiency of achieving benefits, rather than their magnitude, Figure 17-6 would suggest Alternative C as the logical choice. Since the objective of the feasibility study is to develop a workable alternative, the cost-based performance indicators of Figure 17-6 must be emphasized in reaching a decision. In that regard (referring to Table 17-2), it should be noted that only Alternative C has an IRR which exceeds the risk-free rate of 9 percent, and this results only from ridership higher than base conditions.

A number of other factors discussed in prior chapters have a bearing on the evaluation of alternatives, specifically energy, environment, and implementation risk.

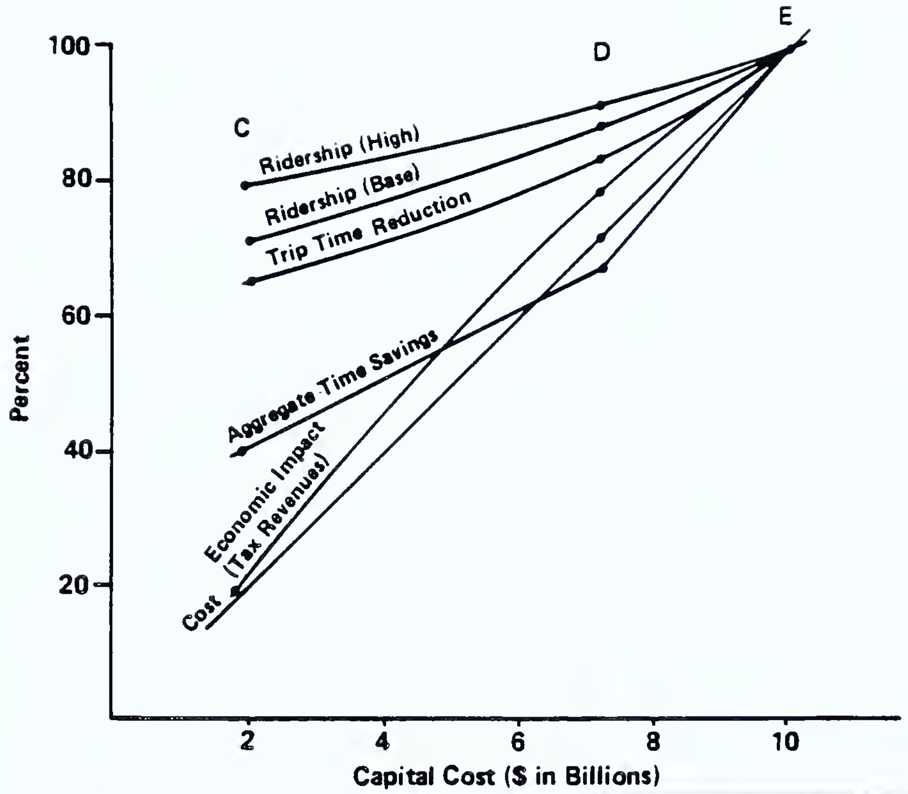

Figure 17-5
Normalized Performance Indicators vs Capital Cost

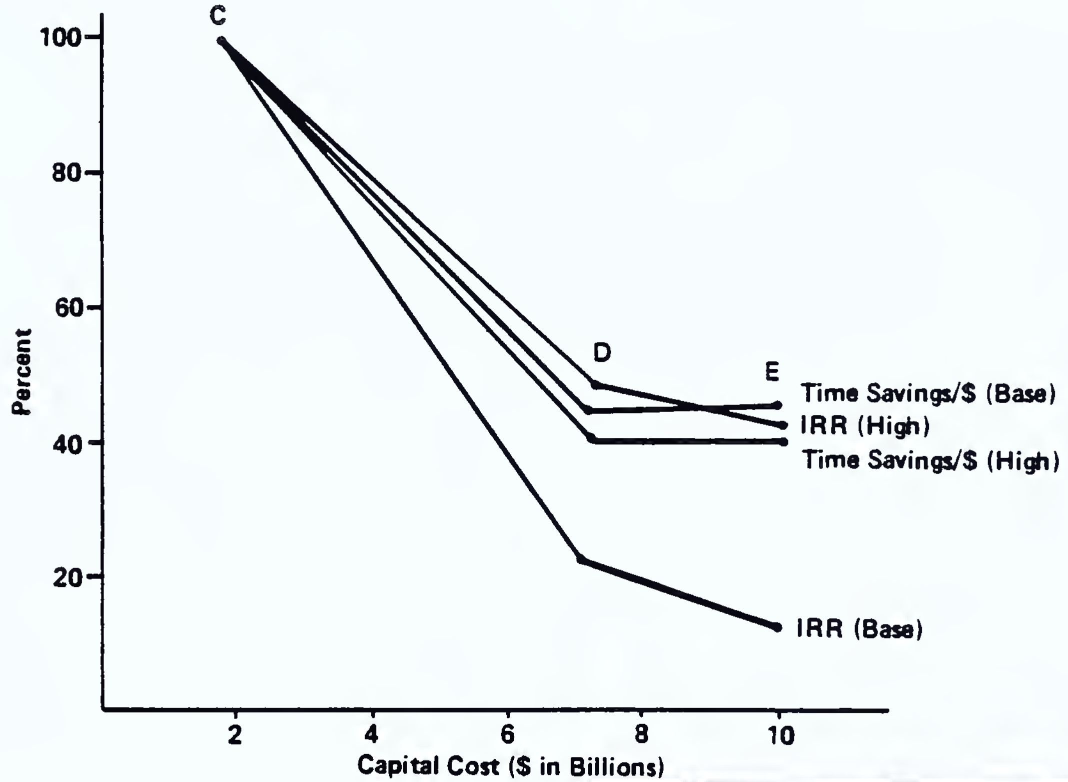

Figure 17-6
Normalized Cost-Based Performance Indicators

As discussed in Chapter 5, energy constitutes only a small portion of the resources consumed in operating an HSR service. In addition, the differences in energy consumption rates among the alternatives are not large, nor is the total amount of energy savings stemming from use of one HSR alternative over another significant with respect to total energy consumption. Energy should not be an important factor in choosing among the alternatives.

Environmentally, HSR is a relatively good neighbor. This is particularly true for Alternative C, where maximum use of existing right-of-way is achieved. While the environmental impact of any HSR alternative is not expected to be severe, it is reasonable to expect (based on the discussion in Chapter 15) that Alternative C would have the lowest impact and Alternative E the highest impact, with Alternative D closer to Alternative E than C. A key element of the environmental disruption caused by implementing an HSR project is the length of new route which would be constructed, which is 50 miles for Alternative C, 154 miles for Alternative D, and 238 miles for Alternative E.

From the standpoint of implementation risk, the three alternatives are far from equal. Alternative C uses essentially-existing technology which is time-tested with the exception of the carbody tilt system, which has been a source of operating and maintenance problems. Alternative C has little implementation risk; however, there is an inherent risk of service deterioration upon failure of the carbody tilt system. This problem must be addressed in later stages of the program.

Alternative D also employs technology which has significant service experience, although not in the United States. The Americanization of the rolling stock and the closer tolerances required of the track structure are the largest challenges to implementation of Alternative D. As this alternative embodies significant new line construction, there is a greater risk of problems obtaining environmental and other necessary approvals, in comparison with Alternative C.

Alternative E uses Maglev technology which has not been revenue-service-tested anywhere in the world at the speeds anticipated in this study. It has been tested at high speeds on an experimental basis, including manned tests, but never on a continuous, revenue service basis, except at quite low speeds (Birmingham, England Airport). Maglev technology has unquestionably established its technical feasibility. Among the questions which remain to be answered are its overall reliability, particularly in the harsh winter environment of Pennsylvania's mountains; the actual cost of civil construction of such a system; the actual cost and reliability of the propulsion and control system; the comfort level at high speeds; and the potential problem caused by irregular settlement of the guideway. In addition, Maglev relies most heavily on new right-of-way, is not compatible with existing railroad plant, and therefore requires absolutely dedicated facilities everywhere. Obtaining such facilities which are compatible with Maglev's speed requirements and which also do not interfere with local highway and other transport facilities implies a significantly greater amount of elevated structure than in Alternative D. As a direct consequence of this requirement, the potential risk of failing to obtain the necessary construction permits for Alternative E is the highest of any of the alternatives considered, and is perhaps an order of magnitude greater for Alternative E than Alternative C.

Since Maglev technology does not permit intermixing with conventional rail service, there is also a strategic issue: Should the potential HSR services of neighboring Western states and the existing NEC rail service permit through-train operation over the HSR trunk of the Commonwealth? Pennsylvania is still very much the Keystone state in this regard.

17.4 SUMMARY

Table 17-3 summarizes the salient features of Alternatives C, D and E from the standpoints of alignment, trip time, ridership, capital cost, rate of return, employment impact, tax revenue impact, environmental impact, implementation risk, and compatability with potential through service.

The selection of an alternative by the Commission for continued study in Phases 2 and 3 of the feasibility study is a preliminary step toward the point of determining if a system should be implemented in Pennsylvania, and, if so, what system. The decision to be reached at this point concerns which alternative route and technology type should receive more detailed evaluation in Phases 2 and 3.

In essence, this selection narrows the range of decisions which must eventually be made, but which are not implicit in choosing one of the three alternatives. Regardless of which alternative is selected, a range of vehicle options will be considered in Phase 2. A finding of the study is that a station at State College adds significantly to system ridership. Although this option was studied in connection with Alternative D, its application to Alternatives C or E is not precluded in Phase 2. Other considerations such as providing for system growth and further improvements can be addressed as the study progresses.

The fundamental questions that are raised at this stage of the study and for which guidance of the Commission is required prior to entering Phase 2 are:

- o Which technology should be given further study for potential application in Pennsylvania -- the range of high-speed rail technology or magnetic levitation?

- o If high-speed rail technology is selected for further study, should the focus be on essentially-existing rail rights-of-way (such as Alternative C with 50 miles of new route construction) or on a largely-new right-of-way (such as Alternative D with 154 miles of new route construction)?

The analyses and findings presented in this Phase 1 Preliminary Report should provide the Commission with the information needed to evaluate the issues posed by Pennsylvania HSR and to provide the guidance needed to continue into Phase 2.

TABLE 17-3

ALTERNATIVE EVALUATION SUMMARY

	C	D	E
Name of Alternative	Improved existing	HSR	Maglev
Equipment type	Tilt body	Electric HSR	Maglev
Route Length (miles)	340.1	314.3	313
Miles of New Route	50	154	238
Percent at grade	90	73	67
Percent elevated	9	23	30
Percent tunnel	1	4	3
Trip time (hours:min)	3:58	3:16	2:36
Ridership (millions/year)			
Base Demand	4.18	5.15	5.87
High Demand	10.26	11.68	12.66
Capital Cost ($ in billions)			
Base Demand	1.84	7.17	10.0
High Demand	1.88	7.21	10.1
Internal Rate of Return (%) (Public Sector)			
Base Demand	4.7	1.0	0.5
High Demand	14.7	7.1	6.2
Employment Impact			
Construction Period (person-years)	18,000	75,000	97,000
Operating Period Jobs	8,300	9,600	12,500
Increase in Pa. Growth Rate (%)	23	27	35
State Tax Revenues ($ in millions)			
Construction Period, Total	95	385	490
Operating Period, Annual	13	15	19
Environmental Impact	Probably not significant	Significant but can be mitigated	Significant can be miti
Implementation Risk	Lowest	Medium	Highest
Compatible (with potential through service)	Yes	Yes	No

APPENDICES

APPENDIX A
DETAILED TRAIN DESCRIPTIONS

Chapter 5 introduced candidate trains for use in the Pennsylvania Corridor. A more detailed description of the following six equipment designs is provided below:

- HST
- LRC
- AEM-7/Amfleet
- TGV
- Series 961
- IC-E

A detailed description of Maglev technology follows in Appendix B.

A.1 HST TRAINSET

Often referred to as the HST (High Speed Train), British Rail's (BR) Inter-City 125 is a high-performance diesel-powered train consisting of seven or eight passenger cars coupled between a pair of lightweight diesel-electric locomotives. It was designed to provide a balance speed of 125 mph on level tangent track. For the Pennsylvania Corridor under Alternative C, an 8-car train with approximately 460 seats would be required to handle the base demand.

In most respects, the HST is a relatively conventional train using cars that are easily coupled and uncoupled to vary the consist, although the operating policy is to work the equipment as a unit train. The inspection, service and maintenance plans for motive power and cars have been integrated; cars and motive power are shopped together.

A distinctive feature of the HST is the placement of a locomotive at each end of the train in combined pull and push operation.

Locomotives: Designated Class 253, the lightweight HST locomotives are powered by the Paxman "Valenta" diesel engine. The Valenta is a version of the "Ventura" which has undergone a weight reduction program to meet HST axle load requirements; the Ventura entered service about 1966.

The HST's Valenta is rated at 2,250 brake horsepower at 1,500 rpm; it is a turbocharged, 4-cycle, V-12 engine. The Valenta turns three alternators: one for traction, one for auxiliaries, and one to supply head-end power (HEP) to the passenger cars. The main alternator is rated at 1,590 kW, the auxiliary supply alternator: 33 kW at 110V, and the HEP alternator: 420 kW at a nominal 850 V. Unlike the American F40PH, Valenta engine speed is not held constant but varies with throttle position; this causes the frequency of the auxiliary alternator output to vary between 33 and 50 Hz. A constant Volts per Hertz relationship is used to permit use of fairly conventional induction-motor-driven devices such as blowers.

Locomotive mechanical problems have centered on turbochargers, exhaust manifolds, and the cooling system. The manufacturer, GEC, is providing an improved design manifold along with other modifications. Overheating, a problem during hot weather, is attributed to leakage, and perhaps an undersized radiator. Turbocharger failures are attributed to high engine temperatures that occur when coolant level drops because of leakage. The Australian version (the XPT) has larger radiators and operates with its Valenta downrated to 1,980 hp.

The locomotive is of the carbody construction type, to obtain the most favorable overall strength-to-weight ratio. The front of the locomotive is tapered back from the leading edge of the nose at floor level. The engineman's windshield is flat and fitted within the nose contour. The cab is air conditioned and quiet. The rear end of the locomotive contains a small baggage room and a guard's room.

Passenger Cars: The Mark III coach represents a new design. All passenger accommodation is located in open cars rather than traditional European compartments. First-and second-class cars share a common body and auxiliary equipment layout.

The carbody, at a 75-foot length, is nearly 10 feet longer than the Mark II car with a corresponding increase in seating capacity but no increase in weight (70,600 lbs, without trucks). The body shell is built of all-welded, integrally-stressed steel to provide a good strength-to-weight relationship.

The Mark III is built in two versions: one for the HST, the other for conventional locomotive-hauled trains. The HST version uses three-phase rather than single-phase trainline power, and carries HST locomotive MU control trainlines. Because of different electrical requirements, the couplers of the two types of Mk III are incompatible; the cars for HST use solid-shank, buck-eye couplers rather than BR's standard buck-eye and buffer type. Car equipment is carried in streamlined undercar compartments accessible from the side of the car by top-hinged doors. A modular design approach has enabled maximum use of common components and systems.

Special Features

Operational Flexibility: The HST is operated as a bi-directional train with locomotives at each end. This eliminates train or locomotive turnaround at the terminals. Changes of consist are easily made. However, there is no provision to add locomotive units for additional power as no multiple-unit connections are provided at the cab ends. A concealed coupler is available for towing a disabled HST, should this be necessary.

Low Axle Loads: British Rail Engineering examined proposed routes and timetables for operation of a high-speed trains. These investigations indicated an installed power requirement of 4,500 hp. The selection of the actual power equipment became dependent on the necessity to minimize the dynamic loads of wheels on rails at high speeds; thus, both low locomotive static axle load and low unsprung mass were established as design objectives.

A diesel solution was selected, but it was not possible to install the requisite total power in one unit within the axle load limitations, thus it was decided to adopt the concept of a multiple-unit locomotive, with one unit at each end of the train.

The development of the Paxman Valenta engine was a key contribution to the 77-ton weight for the 2,250 hp locomotive, as the Valenta has a specific weight of less than 7 pounds per horsepower, compared with about 12 pounds for the EMD 645E-series engine in the F40PH, the Amtrak diesel locomotive used in the Pennsylvania Corridor.

Carbody Construction: The locomotive carbody is about a foot and a half longer than the F40PH, but not as wide or tall. The cab is built as a separate module, using impact-resistant, glass-reinforced plastic of sandwich construction with inner and outer glass fiber layers and a core of polyurethane foam. The module is mounted to the underframe on resilient mounts for crew comfort. No collision structure is provided ahead of the cab. The rest of the carbody is of welded mild steel and has a stressed-skin side construction with removable roof section to permit engine changeouts.

The cars are of welded mild steel in a semimonocoque shell to provide reasonably light weight at a moderate first cost. Undercar equipment is contained in side and bottom enclosures to reduce aerodynamic drag. Vestibule side doors are wide-access, hinge-mounted, and open outward when unlocked and pushed from within.

Trucks: While truck construction for both cars and locomotives is fairly straightforward, the truck designs employed for both are noteworthy in their simplicity and consideration for ride quality.

The locomotive trucks employ a welded-plate steel frame and air-operated, cheek-mounted disk brakes on all wheels. Coil springs are used for the primary and a flexicoil arrangement for the secondary suspension. Traction motors are truck-frame-mounted to reduce unsprung weight.

Car trucks also have fabricated frames, disk brake rotors mounted to the wheel plates, primary coil springs, and a swing-hanger-mounted secondary air supsension system.

Passenger Appeal

The external appearance of the HST is pleasing, and the trainsets are painted in distinctive blue, yellow, and gray colors. The train was designed as a unit with a streamlined locomotive at each end; the cars and locomotives present a continuous appearance because both were designed to the same exterior cross-sectional dimensions.

The relatively wide swing-out doors make entry with luggage easy. The sliding doors that permit entry to the vestibule are automatically operated by treadmats on each side of the door, which further aids the passenger with luggage.

All passenger accommodations are located in open cars; this contributes to a sense of spaciousness in cars narrower than those found in the United States. This impression is aided by side windows that are larger than those on existing Amfleet equipment. The use of light shades of color also contributes to the brightness of the interiors as opposed to the darker browns found in Amfleet cars.

Passenger Comfort

Ride Quality: Insufficient data were available to quantitatively evaluate HST ride quality. However, the experience of a number of trips on this train between 1977 and 1984 provides the basis for an objective assessment of ride quality as "very good." Standard British Rail maximum unbalance in curves is 4 inches (4.2 degrees of cant deficiency), which permits higher speeds in curves than the U.S. practice where 3 inches of unbalance is standard for passenger comfort.

Interior Noise: British Rail personnel reported an interior noise level of 65 dB(A) measured by BREL (British Rail Engineering Limited, the manufacturing arm of BR) during a 125 mph test in 1973. (Data available on the Amtrak F40PH/Amfleet train indicate noise levels to be between 68 and 72 dB(A) at speeds of 80 to 100 mph.) Subjective observations of the HST in service resulted in an assessment of quietness sufficient to enable conversation at a reasonable voice level.

Environmental Conditioning: The air conditioning system is stated by BREL as having the capability to hold interior temperature at 70 degrees F over an ambient range from 21 to 82 degrees F. This performance is definitely inadequate for North American operation and would require considerable increase in capacity to satisfy the -20 to +100-degree F range found in Pennsylvania.

Operational Safety

Passenger and Crew Safety: The coaches present no particular fire hazards, and ordinary portable fire extinguishers should be adequate. The locomotives are equipped with portable extinguishers and also a fully automatic PVB (Polyvinylbutyral) manifold extinguisher system. This system can be actuated by pull handles in the cab and on the exterior, as well as by automatic heat and smoke detectors. Any of these will automatically shut down the engines down and activate the fire protection system.

The coaches have wide entrance doors at the ends leading to the vestibule, from which there is access to the exterior doors that manually open outward for emergency egress.

The steel carbodies of the HST locomotives and trailer cars are similar in design, but heavier sections are used on the locomotive. The underframe, fabricated mostly of 10 mm steel plate, is essentially two side sills with cross members and deep body bolsters. There is no center sill to carry heavy buff loads.

The locomotive will not pass the 800,000-pound compression test, recommended by the AAR and enforced by the United States Code of Federal Regulations, because the design strength at the center line of the draft sill is only 331,000 pounds. The passenger cars do not meet the 800,000 buff criteria recommended by the AAR (but no longer enforced for the design of trailer cars), because the design strength at the center line of the draft sill is only 441,000 pounds for the coaches. The strength at the collision post attachments is 38,000 pounds. The cars are equipped with a solid shank coupler without the traditional buffers of UIC practice, but could be fitted with AAR tightlock couplers. The Mk III is a light car, weighing only 87,000 pounds.

The windshield material has high impact resistance. It is nearly 1 inch thick, and the thin, toughened inner and outer facing glazing materials are laminated with a thick interlayer of PVB. It can withstand the impact of a 2-pound steel cube striking it corner-on at 180 mph, without penetration.

Vehicle Safety in Curves: Insufficient vehicle data were provided by BREL to render an analysis of steady-state curving characteristics for the HST.

Crashworthiness: The locomotive's operating cab is equipped with a glass fiber nose which is probably not strong enough to provide much protection to the crew in the event of accidents as severe as grade crossing collisions. (Under Alternative C, however, grade crossings would presumably be eliminated.) Because the couplers are not of a tightlock design, they will not resist climbing in the event of a crash or derailment. However, the vestibule carrying plates have been designed to prevent the couplers from "riding out" (disengaging through vertical motion).

Development Status

The HST has been operating in the United Kingdom as the Inter-City 125 since 1975. It uses conventional components and subsystems that have been proven through experience on British Rail's main lines.

Americanization

Americanization of the HST involves the incorporation of certain modifications to bring the trainset into compliance with structural requirements required for passenger equipment on common carrier track in the United States. The rationale for modifications is based on the findings of the HST, IPEEP report.[1]

Structure: The welded mild steel semimonocoque locomotive structure is reasonably lightweight but would require considerable reinforcement to comply with the requirements for compression strength found in the United States Code.

Collision protection for the locomotive crew is significantly less than provided in the F40PH locomotive. While the glass fiber composite laminated cab provides excellent energy absorbing protection against major debris, the buff-strength design of the underframe allows only 330,700 pounds capacity. No structural reinforcement is provided ahead of the cab to prevent overriding by another train or by a highway truck in the event of a grade-crossing accident.

Coaches have a buff strength of 441,000 pounds and have collision posts; however, this strength is still only slightly more than half of the U.S. recommended practice. Solid shank buck-eye couplers are not of a tight-lock design that would resist car overturning or overclimbing to the same extent as the AAR type H coupler.

Seating: As operated in Great Britain, the coaches are configured for 48 first-class or 72 second-class seats. First-class seating is 2-and-1; second class is 2-and-2. Two types of dining cars are operated: one, kitchen-equipped for offering full meals and used on longer runs, seats 23; the other, a buffet service car similar to Amtrak's Amcafe, seats 34.

Because the narrow width of the HST coach cannot accommodate 2-and-2 seating with Amtrak seat widths, 2-and-1 seating must be considered. By orienting seats in one direction rather than all seats facing car center, more rows can be accommodated. The Amtrak equivalent car arrangements are estimated to be a coach with 54 seats and a cafe/coach with 36 seats.

Cab Signals: A cab signal or other protective system would be required that is compatible with whatever system is installed in the corridor.

Doors and Steps: Moderately high-level station platforms are in use throughout the British Rail system that are about a foot lower than the platforms in use in Philadelphia and Lancaster. For this reason, there is but a single-step stairwell in the HST coaches, which have the same floor height (above the rail) as single level coaches in the United States. Special platforms would have to be built, or if entry is to be made without benefit of high-level platforms, a portable step may be necessary for each coach, or a trap added to each coach, to cover the gap caused by the one-step stairwell opening.

Capital Cost

BREL's non-profit price of a 1-7-1 HST to British Rail is approximately $4.97 million, quoted during a visit to BREL in Derby, England, in May 1984. This breaks down to $1,615,000 per locomotive and $248,500 per coach based on an average of car types. To this figure must be added spares and profit which would bring the estimated price of a 1-8-1 consist for Pennsylvania to approximately $6.5 million FOB Derby, exclusive of modifications.

A.2 LRC TRAINSET

The LRC is a high-speed, diesel-powered train consisting of one or more locomotives and from 4 to 10 separable passenger cars. The acronym LRC signifies its design objectives: Light, Rapid and Comfortable. In the design of the trainset, particular emphasis was placed on suspension systems that permit speeds through curves that are higher than those allowed by superelevation compensation. A banking-carbody system is offered on the cars to provide passenger comfort in compensation for unbalance beyond that available from track superelevation. The locomotive is not equipped for body banking, but its low center of gravity allows higher curve speeds than obtained by more conventional locomotives.

The normal train consist is one locomotive and up to 5 cars for single-directional use, or two locomotives, one at each end, with as many as 10 cars between for simultaneous pull and push operation. Multiple-unit control trainlines are provided for this purpose. For very high performance (maximum acceleration and balance speed of 125 mph on tangent track) the train may be operated in a 1-5-1 or 1-6-1 consist (e.g., a locomotive at each end of a five- or six-coach consist). This is the configuration selected for Alternative C.

The train was designed and developed over a 12-year period (1967 to 1979) as a joint venture of Bombardier, Alcan, and Dofasco, three Canadian railway equipment manufacturers. VIA Rail Canada operates the LRC in corridor service between Toronto, Montreal and Quebec City.

Bombardier provided the motive power and is responsible for the LRC's detailed engineering, interior appointments, systems and equipment, program management and marketing. Alcan Canadan Products Limited was responsible for the structural design and testing of the LRC coach, and supplied the weldable aluminum plate, sheet and extrusions. Dofasco Inc. was responsible for the design of the coach and locomotive trucks, the smooth-ride suspension system and the all-important automatic banking system.

Locomotives: The locomotive is a full-width, box-cab design with the engineman's cab close to the front end to provide visibility. The front end is steamlined to minimize aerodynamic drag in both the leading and trailing locomotive configurations.

Each locomotive is powered by the Alco Model 16V-251F diesel engine. This is a four-cycle, turbo-charged engine which develops 3,720 hp at 1,050 rpm. The diesel drives four alternators: The first is the traction alternator which is bolted to the prime mover and provides a three-phase, variable-voltage output, which is rectified to supply the traction motors. Two 250 kW HEP alternators are bolted to and driven by the traction alternator; these provide a total of 500 kW (480 Vac, 3-phase, 60 Hz). The fourth is the generator for auxiliaries.

Bombardier has a new, lightweight diesel locomotive under development that would utilize a 12-cylinder engine. This new version was studied under Alternative C. Also considered under Alternative C-Electric was a lightweight electric version of the LRC, which has been proposed as a further development of the original diesel-electric LRC train.

Passenger Cars: LRC cars are designed and configured to suit a variety of passenger services. The basic coach has an overall length of 85 feet and is 10.5 feet wide. Ample interior floor space, 7-foot-high-ceilings, and large windows provide a spacious atmosphere. The VIA Rail Canada seating arrangement provides for 74 seats in coach and 58 in the club car. Fully loaded, the coach weighs 105,000 pounds.

The coach is equipped with one vestibule, two toilets, an electrical locker and a luggage and coat rack. The luggage racks have been converted to aircraft-type overhead bins with hinged doors. The floor is carpeted. All fasteners are isolated to eliminate any direct temperature or sound path to the coach interior. Each VIA car is equipped with a galley.

The LRC coaches are equipped with a carbody-banking system. This system enables the train to maintain high speeds on curved track by banking into the turn to counteract discomfort resulting from centrifugal force, if the track does not have sufficient superelevation to provide a high balanced curve speed.

Special Features

Operational Flexibility: Changes in consist can be made as readily as with standard Amtrak equipment.

Lightweight Construction: The use of aluminum in the construction of the LRC yielded significant savings in weight for the locomotive and coach car bodies. Of particular interest is the fact that the LRC meets all AAR requirements and, in the case of the locomotive, provides superior crew protection from impact with objects on the track.

Carbody construction employs extensive use of aluminum extrusions with a particularly heavy side sill, which protects passenger spaces from side penetration. No center sill is used, the draft and buff forces being transmitted to the side sills through steel end underframes. Carbody bolsters are of aluminum.

The underside of the car is completely enclosed between the trucks, giving a full streamlined effect and providing a protective equipment compartment. Access is through hinged side panels.

The locomotive has a depressed center platform fabricated of steel, with the engine recessed into the center section for low center of gravity. The twin fuel tanks are arranged on each side of the recessed engine section below the floor platform.

The aluminum locomotive shell is essentially non-stressed; however, a massive aluminum collision structure, concealed by the shaped nose, provides crew protection.

Trucks are of cast steel. Both the locomotive and the coach are heavier than specified because of unplanned truck weight increases that occurred in production.

Banking System: The LRC passenger car trucks are made of two major parts, the truck proper and the body banking system. The banking mechanism consists of a tilting bolster supported by a swing linkage mounted on the truck frame. The linkage puts the roll axis at about the passenger hip, seated position, and below the center of gravity of the coach body. This provides maximum passenger comfort because there is minimum translation of the passenger's body.

The banking torque is provided by two hydraulic cylinders mounted diagonally between the tilt bolster and the truck frame.

Power to the hydraulic cylinders is supplied by an electrically driven hydraulic pump packaged in a single module containing the reservoir, accumulators and hydraulic control elements. This is mounted in the center of the coach under the floor. An accelerometer mounted on the tilt-bolster is aligned to measure lateral accelerations. The accelerometer signal operates a hydraulic servo valve which controls the actuating cylinder and tilts the bolster and the carbody. The resultant position change reduces the lateral accelerations perceived by the accelerometer. Banking stops when the difference between the components of gravity and lateral accelerations falls below the detection threshold of the accelerometer.

Designed to be fail-safe, the system employs conventional hardware. In the event of a malfunction, the system returns the carbody to neutral and locks it in this position, while the remainder of the suspension system is unaffected by the servo failure.

The banking system underwent extensive safety and reliability evaluation by VIA and Bombardier before being certified for fleetwide operation. The phased review program concentrated on three elements—safety, reliability and performance--and resulted in modifications and improvements to the banking systems of the 100-car fleet.

From the safety standpoint, the primary concern was to train VIA maintenance personnel to make sure they understood the type of service the system requires, and to ensure that all components operated in the proper sequence. From the reliability standpoint, each component was analyzed and tested to eliminate premature failures. From the performance standpoint, the system was subjected to an in-service test of system response times.

Passenger Appeal

The interior compartment cross section and length of the LRC are very similar to that of Amfleet equipment. The large, high windows contribute to the appearance of interior spaciousness. However, the application of standard Amtrak corridor seating density (84 passengers per car) would place some seats next to a window post. Baggage accommodation is about equivalent to that of an Amfleet car although the overhead storage racks improve appearance and baggage security. General aesthetic appearance is considered to be an improvement over Amfleet equipment.

Passenger Comfort

Ride Quality: Ride quality was predicted in both the vertical and lateral direction on tangent track representative of the Northeast Corridor.[2] The subject LRC review states: "The overall trend was a decrease in comfort with increasing speed, as would be expected. However, the ride is rated as 'good' to 'almost good' at speeds as high as 125 mph." A ride quality analysis was also performed on the Amfleet coach. The subject LRC review report states: "The ride index curves suggest that the LRC coach is overall a slightly more comfortable vehicle to ride in than the baseline (Amfleet) coach."

Interior Noise: The LRC coach was designed to meet NC 60 (noise contour) as an objective. This International Standard Organization "constant nuisance level noise contour" corresponds to a dB(A) level of 66. The prototype coach performed to about 70 dB(A) when tested in 1971.[3] Subsequent modifications to the suspension, and heating and ventilating fans have been made, so that the noise levels in the coach are now lower. Subjective assessments indicate that the coach allows conversation at normal levels.

Environmental Conditioning: Heating capacity of the LRC coach exceeds that of the Amfleet cars, while air conditioning capacity is the same. The LRC equipment is designed for North American weather conditions and is suitable for the Pennsylvania Corridor without modification.

Operational Safety

Passenger and Crew Safety: The train was designed for and tested against FRA/AAR requirements, and meets those standards. It does not differ radically from conventional equipment; therefore, the safety of passengers and operating crew should be the same as for the F40PH/Amfleet train.

Diaphragm openings are adequate. Clearances while cars are negotiating sharp curves are sufficient and do not present problems. The folding-step, sliding-door arrangement causes no passenger safety problems.

The locomotive has a relatively standard cab and control arrangement, although the usual control stand has been replaced by a console-type arrangement.

No special firefighting equipment appears to be needed on the coaches. A standard fire extinguisher and standard wrecking tools are adequate. Seat materials, upholstery, carpeting and interior trim are of fire-resistant materials.

The banking system is a "fail-safe" system, returning to a normal neutral position in the event of control system failures.

Vehicle Safety in Curves: Both the LRC locomotive and passenger car have been extensively tested to determine safety margins for: a) vehicle overturning, b) wheel climb, c) rail rollover, and d) track panel shift.

A report[4] prepared for FRA concluded that the limiting test proved to be that for vehicle overturning, and that maximum safe cant deficiency for the train is set by the coach at 12.5-inches of unbalance. It was further concluded that: "The LRC train can run at 9 inches of cant deficiency while maintaining less than 0.1g steady state lateral acceleration by banking the coaches, and that a train consisting of the AEM-7 locomotive and standard Amcoaches with Pioneer III trucks can run safely at 8 inches of cant deficiency at the expense of 'strongly noticeable' steady state lateral acceleration."

Crashworthiness: The LRC was designed to meet U.S. standards for compressive buff load, anticlimber strength, collision post attachment, truck attachment, and coupler carrier thrust load. The LRC coach has the distinction of being one of the few non-domestic vehicles that has passed the AAR interchange service requirements. Meeting the 800,000-pound buff strength requirement is considered to be a positive influence when evaluating passenger safety. Examination of the carbody design in the course of the IPEEP train reviews indicated a satisfactory safety margin in the roof, side, and underframe areas, and it was felt that the LRC car offered passengers a better-than-average margin of safety. The draft gear and coupler arrangement was also favorably reviewed at that time.

Development Status

Both the improved diesel-electric and the all-electric trainsets must be considered in the design category with no operational experience as complete trainsets. However, design and operating experience gained with the first three LRC orders (one with Amtrak, two with VIA) has enabled Bombardier to modify and improve the LRC design.

The first diesel-powered LRC trains equipped with carbody banking systems (50 cars) were delivered to VIA Rail Canada in July 1981. Shakedown and acceptance tests began at that time. Deliveries continued until sufficient numbers of trains were available to begin limited service in March 1982. Full-scale operations began in June of that year. VIA now has 33 LRC locomotives and 100 LRC cars in service.

Early problems experienced by VIA were of a minor nature, according to VIA's chief mechanical officer. It has been reported that there were no major difficulties with the banking system; modifications were made to the coach electronics and the banking system to improve reliability.

VIA operates over track owned by the Canadian National Railroad (CN), and the Canadian Pacific Railroad (CP). These railroads also perform vehicle maintenance under contract to VIA. One of the results of this relationship was a delay in initiating a banking-system maintenance training program for shop personnel at a time when VIA was undergoing considerable economic retrenchment.

Another factor that delayed introduction of banking service was the uncertainty of CN and CP concerning vehicle lateral loads on their track at higher curve speeds. Resolution of this uncertainty required a lengthy period of time to make banking tests, make system modifications, make more tests, and certify the equipment for unrestricted operation.

In short, the banking system underwent extensive safety and reliability evaluations by VIA and Bombardier. As a result, modifications and improvements were made to the entire 100-car fleet before it was certified for fleetwide operation at the end of October 1984.

Wheel-bearing axlebox fatigue problems occurred in December 1983. Bombardier immediately notified VIA that the 50 passenger cars then in service should be taken out of service for inspection and rework. Failures were attributed to poor load distribution in the bearing housings. After the housings were remachined, the trains were put back into service.

Americanization

The LRC was designed to satisfy North American safety requirements and to provide passenger accommodations typical of the United States and Canada, hence no structural modifications are necessary. Performance calculations made for the LRC in this program assume standard Amtrak seating (i.e., 84 in coach, 60 in cafe car), in a basic 1-4-0 consist (312 revenue seats). An alternate 1-6-1 consist also was examined.

Car Clearance: Although the LRC is designed to meet all North American interchange clearance restrictions, the coach presents a borderline case when banked "full over", and slightly exceeds the construction limit outline applicable for tunnels along the Northeast Corridor (Figure A-1).[5] The prototype car is shown; there have been no major changes in the carbody, although changes may have occured in the suspension. Clearance must be examined in detail in the Pennsylvania Corridor before deciding on the car outline requirements.

Capital Cost

The following estimated prices may be used for budgetary and planning purposes in 1984 according to Bombardier:

Locomotive	$1.5 million
Coach	$1.0 million

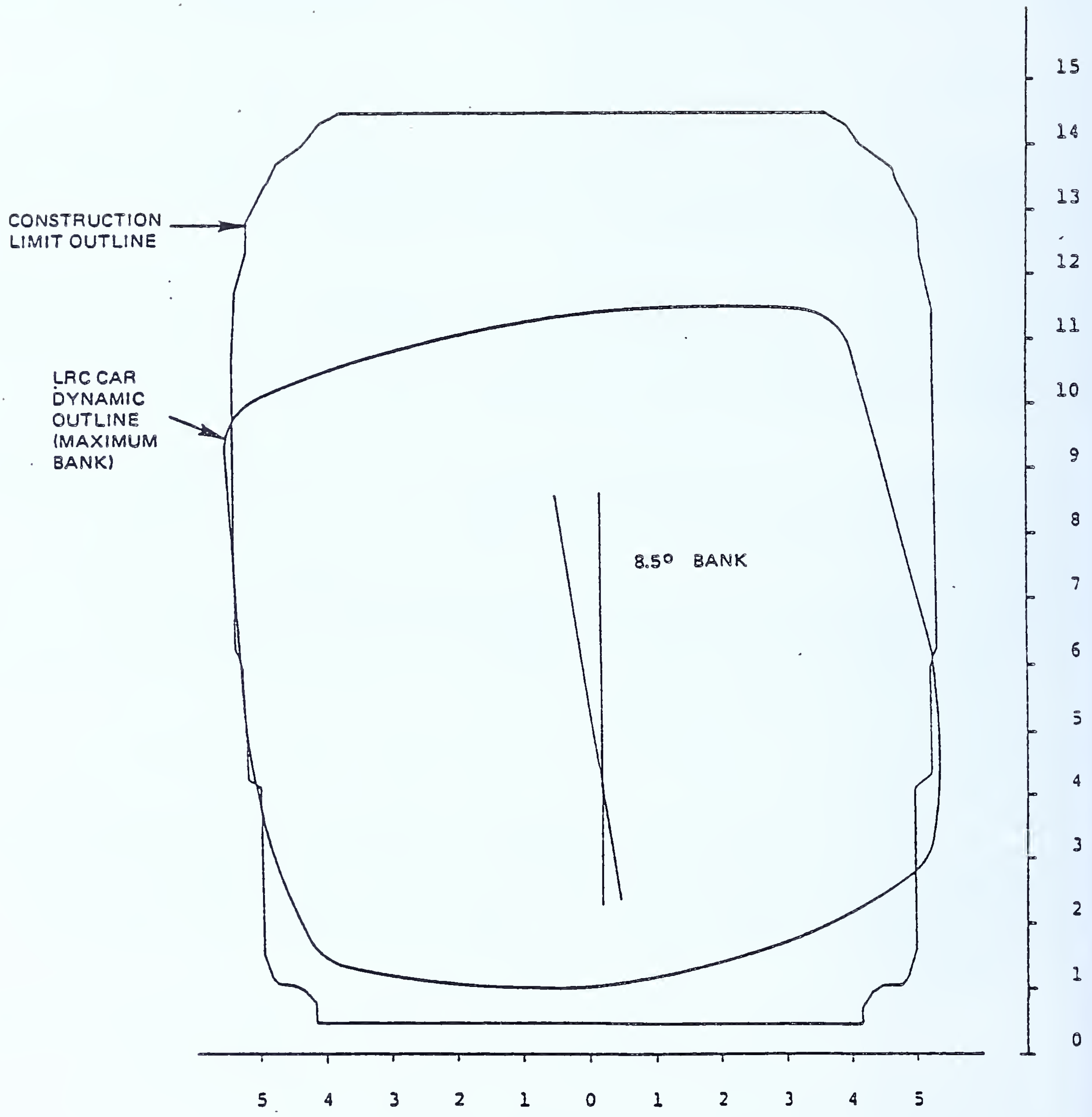
CONSTRUCTION LIMIT OUTLINE
LRC CAR DYNAMIC OUTLINE (MAXIMUM BANK)
8.5° BANK
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
5
4
3
2
1
0
1
2
3
4
5

FIGURE A-1: NORTHEAST CORRIDOR CONSTRUCTION LIMIT OUTLINE, LRC COACH, MAXIMUM BANK

This price does not include tariff, modifications, spare parts, maintenance manuals, special tools, etc.

A.3 AEM-7/AMFLEET TRAIN

The AEM-7 locomotive with Amfleet cars represents the conventional approach to a passenger train consist in that a separate electric locomotive and individual (i.e., separable, nonarticulated) cars are used. Auxiliary electrical loads on the cars are provided for by a trainline from the locomotive carrying Amtrak's standard 480 V, 60 Hz, three-phase power. A standard compatible system of power jumper cables is used between cars, in addition to a control trainline for door interlocks, electric brake control and communications.

For Alternative C, the base case consist is one AEM-7, five Amcoaches seating 84 passengers each, and one Amcafe (snack bar/coach) containing 60 revenue seats, which provides a total of 480 passenger seats.

Locomotive: The AEM-7 is a double-ended locomotive with a box cab at each end. It is rated at 4540 kW on a continuous basis (approximately 6000 kW, short-time). A static inverter provides 500 kW of head-end power for train lighting, heating and air conditioning. The locomotive is capable of operating on three different wayside power supply systems: 11 kV/12.5 kV, 60 Hz, and 25 kV, 60 Hz. The four-axle locomotive uses four ASEA LJH 108-1A frame-mounted traction motors to obtain low unsprung weight. Dynamic as well as both disc and tread brakes are used; the disc brake pads are applied against special rotors installed on the wheel plates.

Passenger Cars: Amfleet equipment uses a number of seating arrangements; however, two basic car types, a coach and a snack bar/coach (Amcafe) combination, are used here as examples. The coach seats are a two-passenger reversible design which are used facing the direction of travel in conventional North American practice. The seat has an overall width of 47.69 inches and is spaced on a 38-inch pitch. This arrangement provides capacity for 84 passengers in an 85-foot car with a vestibule at each end and two toilet rooms. The Amcafe has 60 seats, a section of approximately 19 feet being used for a food service counter for pre-packaged meals. Amfleet is designed to operate at speeds of up to 120 mph.

Special Features

The AEM-7 is an Americanized version of the Swedish State Railways Rc-4 locomotive. It differs from the Rc-4 in terms of buff strength, tri-current capability, propulsion rating, gearing, dynamic brake, head-end power, air brake equipment, multiple-unit capability and the use of U.S. safety appliances.

The AEM-7 also breaks with domestic locomotive tradition in terms of axle loadings and buff strength. Whereas the usual domestic locomotive axle loading is 32.5 tons, required for starting adhesion in freight service, the static axle load of the AEM-7 is only 25.2 tons. This has been achieved through the use of a proprietary wheel-slip detection system and construction to a lower than normal locomotive compressive strength (e.g., 614,000 lbs vs. 1 million lbs). The latter is permitted for use on the electrified Northeast Corridor because the locomotive is not being used in interchange service, and draft and buff loads in exclusive passenger service do not require the longitudinal strength needed for hauling long freight trains.

Passenger Appeal

Amfleet cars were designed to provide a high level of passenger appeal. They are constructed of stainless steel for strength, durability and appearance.

Operational Safety

The Amfleet cars comply with the requirements, standards and recommended practices of the following:

- o Federal Railroad Administration
- o U.S. Public Health Service
- o Pennsylvania laws
- o AAR recommendations

Development Status

In 1977, Amtrak decided to procure a fleet of lightweight, high-speed electric locomotives as a replacement for its venerable GG-1 locomotives, built by the Pennsylvania Railroad in the 1930s and 1940s.

After evaluating and testing several foreign locomotives, Amtrak wrote its specifications around the Swedish Rc-4 locomotive concept, though with higher horsepower, a more crashworthy frame, a static inverter power supply, and a number of other custom features. The locomotive was to weigh no more than 100 tons (in comparison with the 215-ton GG-1) and was to pull up to eight Amfleet cars with the same trip-time performance as the Metroliners--a formidable task, considering that all Metroliner axles are powered. EMD won the contract and, under a licensing agreement with ASEA, produced 47 ASEA-Electro-Motive-7000 horsepower (AEM-7) locomotives for Amtrak.

A very successful fleet, the AEM-7s have met or exceeded all of Amtrak's specification requirements and are currently used on virtually all intercity passenger trains between New Haven/New York and Washington.

Similarly, Amfleet equipment, developed by the Budd Co. around the Metroliner carbody concept, is Amtrak's standard single-level car used nationwide. There are currently 490 Amfleet I cars and 150 Amfleet II cars in service.

Capital Cost

AEM-7: The total price to Amtrak for the first eight units, ordered in February 1978, was $22 million. In 1979, Amtrak ordered 22 more than a total price of $56 million (including spare parts). In 1981, Amtrak ordered 17 more locomotives for a total price of $50 million.[6]

Unit prices (with spare parts) are as follows:

1978	$2,750,000
1979	$2,545,500
1981	$2,976,000

The price for an AEM-7 locomotive is estimated at $3.2 million per unit, including spare parts, as of January 1984.

Amcoach: The price for an Amcoach is estimated from recent purchases:

a. Amtrak purchased three prototype single-level cars (two sleepers and a diner) as carbody shells without interior furnishings, or trucks, for $2.75 million in March 1984.

b. Amtrak purchased 150 Amfleet II cars (125 coaches, 25 food service cars) for a total price of $150 million in March 1980. Unit price: $1 million.

c. Amtrak purchased 492 Amfleet I cars (362 coaches, 130 food service cars) without interior furnishings, in four orders, at a unit price of from $410,000 to $430,000 between 1975 and 1977. The addition of interior equipment (seats, carpeting) brought the unit cost to $537,000 for Amcoaches and $635,700 for Amcafes. On a weighted basis, this equates to a unit cost of $563,000 per Amfleet I car as of January 1976.

Based on the above recent purchases, a $1.1 million per unit price is estimated for a single-level coach as of January 1984.

A.4 TGV TRAIN

The TGV-PSE is an electrically powered passenger train with a dedicated multiple-unit (MU) locomotive; one locomotive unit is at each end of an articulated section of coaches. SNCF refers to the locomotive units as power cars. The TGV operates daily at speeds of up to 168 mph, but a specially modified configuration set an international speed record of 236 mph. A standard TGV consist is fixed at two power cars and an eight-section articulated coach set. The locomotives may be uncoupled from the coach set.

Locomotives: In addition to two motored trucks on each power car, the end truck of each of the end cars in the articulated car set is motorized, deriving its power from the adjacent locomotive. This arrangement obtains the required low axle load on the drivers while minimizing train weight. The overall train is not an MU consist in the sense that each car is powered; only 12 of the 26 axles are driven by traction motors.

The propulsion and auxiliary systems are designed to operate on 25 kV, 25 Hz on the Ligne Grande Vitesse and 1.5 kV dc on the existing tracks in major French cities. In addition, several trainsets are equipped for operation into Switzerland on 15 kV, 16-2/3 Hz (at reduced propulsion performance). Separate pantographs are provided for ac and dc power collection, and the power is switched between propulsion system components (e.g., controlled rectifier for ac, chopper for dc).

Auxiliary equipment operates from one of three power supplies: 1.5 kV dc; three-phase 220 V, 50 Hz; or a 72 V battery circuit. The 1.5 kV dc, obtained from dc catenary or from a rectified auxiliary winding on the transformer, powers air compressors and train heating. The three-phase current is supplied by two 450 kVA inverters; one inverter is located in each of the end cars adjacent to the locomotive, and provides power for air conditioning, blower motors and battery chargers.

Train braking is accomplished by a combination of dynamic and two types of friction brakes: disc and tread. Tread brakes are applied to powered axles, and disc brakes to unpowered axles. Dynamic brake blending occurs in normal operation; in the event of failure, friction brakes are sufficient to stop the train.

Passenger Cars: The passenger cars are arranged in a fixed consist of eight articulated carbodies. In this design, each carbody is suspended between the articulation joint assembly mounted atop an unpowered truck. The end cars have a conventional powered truck at one end with the articulation joint at the other end. Intercar passenger movement is through an annular ring which forms the structural part of the articulation joint. Individual carbodies are relatively short, with approximately 61 feet between vertical hinge joints of the articulation assembly.

Seating arrangements provide 35 seats in the first class end car, 38 seats in the next two first class cars, 35 seats in the bar car, and 60 seats in each of the four second class cars. This provides a total of 111 first class (1-and-2 across) and 275 second class (2-and-2 across) seats, for a total revenue seat load of 386 passengers.

Special Features

The TGV incorporates a number of innovative features that were integrated into a successful high-speed system design.

Lightweight Construction: The carbodies are of all-steel construction. Power car structure is of semi-stainless steel with the framework having the optimum strength-to-weight ratio. Coaches have integrated roof and sides assembled to the underframe, while power cars have removable roof section for access to the equipment and a somewhat more substantial underframe.

Articulation: Articulated connections of the TGV are made at the truck pivot point in a fairly conventional pivot arrangement except that special provisions have been made to provide a very high spring seat for the flexicoil secondary suspension. This high support point is provided by a fabricated-steel ring having spring seats on each side and an opening through which the walkway and diaphragm extend. This ring serves as a "body bolster." One carbody has a cantilevered extension which rests on a center pivot in the bottom of the ring. A lateral shock absorber near the roof connects the ring and the first carbody to limit roll. The second (adjacent) carbody rests on a cantilevered extension from the bottom of the ring. The eccentricity of this support is offset by longitudinally-acting rubber shock pads between the top of the ring and the end of the carbody near the roof.

This arrangement pivots one car to the ring while shock-mounting the other car to the ring. Direct-acting longitudinal hydraulic shock absorbers between the truck frame and the nonpivoting carbody serve as yaw dampers.

Adjacent carbodies are attached with a vertical restraint which is an anti-climber in the event of a derailment. Jacking is intended to be accomplished using jack pads on the sides of the trucks.

Body-Mounted Traction Motors: An unusual feature of the TGV-PSE is the mounting of the traction motors on the carbody with parallel drive. This arrangement places the motors and attached primary gear units close to the truck frame center transom in the same location as that used with truck-frame-mounted motors. A special cardan shaft connects the primary gear unit to an axle-hung secondary gear unit. Sufficient space is provided in the truck around the motors to permit relative movement of 4.75 inches to either side of center.

By so doing, the power truck has slightly less mass than a trailing truck because of the absence of motors and the fact that the mass of the secondary gear unit is nearly the same as the mass of the four disc brake assemblies located on each unpowered axle.

The cardan shaft between gear units is unique in that an arrangement of three needle-bearing rollers operating within a three-groove internal track take the place of the conventional splined shaft. This design reduces the "sticking" friction in the spline connection to one-tenth the level of a conventional spline, thus reducing transmission of forces that would adversely affect ride quality.

Trainlined Traction Power: An interesting feature of the TGV is the mounting of a cable along the car and locomotive tops to feed 25 kV, 50 Hz power from one locomotive to the other from a single pantograph. A single pantograph was decided on to ensure optimum dynamic conditions between the overhead catenary trolley wire and the pantograph, and to minimize aerodynamic drag. The insulated conductor has an area of 95 sq mm. At the car ends the cable is fitted with sloping, insulated cableheads connected by a flexible cable capable of carrying an operating voltage of 30 kV.

Inverter: The auxiliary system uses two 450 kVA, dc to three-phase ac inverters. One inverter is located in the end car adjacent to the locomotive. Each inverter normally feeds one-half of the train, including auxiliary loads on the adjacent locomotive. In event of failure, one inverter can feed the entire train.

Chopper-Controlled Dynamic Brake: The dual-voltage, dual-frequency corridor requirements of the TGV-PSE require switching ac to dc operation. A controlled rectifier is used for ac operation, while a chopper is used for dc propulsion as well as dynamic braking under all circumstances. Components are switched in such a way that the same components within different circuit configurations are used for all operations. The dynamic braking uses the chopper to control the voltage across the braking resistors.

Operational Flexibility: The TGV trainset is bidirectional. This provides an advantage over a conventional consist, which requires a turning facility. Consist size of the TGV is fixed; however, this places the TGV at a disadvantage, as a car cannot be cut out of the consist if there is a safety-related malfunction.

Passenger Appeal

The external appearance of the TGV was designed to convey sleekness and speed. The predominant color is orange with a broad gray and a lesser white stripe running the length of the train, beginning at the low, pointed nose. The train was designed as a unit, and the locomotives and cars present a continuous appearance.

Interior appointments are tasteful and comfortable. If changed to accommodate U.S. specifications for interior layouts and color schemes, the appearance, decor and amenities may provide a different appearance.

Amtrak-type 2-and-2 seating would provide seating almost identical to that of an Amfleet car, except that aisle width would be slightly reduced because of the narrower width of the TGV carbody. The location of a vestibule at only one end of each car provides fewer doors for the same number of passengers as an Amfleet train. However, the short car length of the TGV reduces the average distance from seat to door, compensating in part for the reduced number of doors and narrower aisles.

The TGV offers baggage rooms adjacent to the vestibule over the truck area, with toilet rooms at the other end. The baggage area is a feature not provided on Amfleet cars.

Side windows are larger on the TGV-PSE than on Amfleet cars. The windows in the SNCF train do not index uniformly with the Amtrak seat pitch in either first- or second-class seating.

Passenger Comfort

Ride Quality: The cars are designed with truck and carbody frequencies separated to avoid any unfavorable effects on carbody ride. The track that the TGV is operated on is built to higher quality standards in terms of cross level, gauge and surface than track currently in place in the United States. The result is that, from an objective point of view, the TGV provides a very smooth ride on both tangent and curved track.

Interior Noise: SNCF specifications called for meeting a number of maximum noise levels to be measured at specific locations throughout the train when traveling at 160 mph. The levels ranged from 63 dB(A) at the center of the passenger compartment to 85 dB(A) measured between cars in the passageway (both of the car-end vestibule doors open).

Investigation of revenue service conditions in mid-1984, on an objective basis, found that noise levels in the cars were low enough to allow normal conversational levels of speech even at maximum train speed.

Environmental Conditioning: The heating system of the TGV may be adequate for service in Pennsylvania; however, the capacity is less than that provided on Amfleet cars on a per-passenger basis.

Air conditioning cooling capacity is 7.6 tons per car which is comparable with U.S. standards on a per-seat basis and should be adequate for operation in

Pennsylvania. A single refrigeration system is used on each car as compared to the divided system used for redundancy on Amfleet cars.

Operational Safety

Passenger and Crew Safety: There seem to be no major fire hazards on the TGV-PSE. Interior materials such as seat covering, carpeting, sidewall and ceiling material are fire resistant. No special firefighting equipment is considered to be necessary.

The braking system is separated into three subsystems. There is a dynamic brake on the powered axles; there are cast iron tread brakes, also on the powered axles, and there are disc brakes on the unpowered axles.

The windows in the passenger area exceed the 1,100 sq in maximum unobstructed area which has been established as an Amtrak guideline, as is the case with most non-domestic trains. The glazing material would need to be nonbreakable to withstand vandalism. There are two escape windows per car; considering the short length of the car, this should be adequate.

The four plug-type side doors (two at each end) are automatically controlled. The safety features of the doors include a safety device that automatically reopens the door should an obstacle prevent normal closing and an emergency device that cancels all automatic features and allows the doors to be opened or closed manually.

Crashworthiness: The comparison of domestic- and foreign-built vehicles on the basis of crashworthiness or other structural criteria is difficult because of the differences in strength criteria and construction techniques.

The compressive strength of the TGV power car does not meet the U.S. 800,000-pound requirement. However, it is built with a protective structure in front of the cab that was designed to absorb frontal shock impacts. The structure extends across the front end of the car framework at the floor and at the bottom of the windshield and is tied to corner posts and a center strut that divides the windshield. It is built of cellular shock-absorbing materials that can absorb 2 million joules of energy. No aluminum is used in the structures or exterior.

The semi-stainless-steel trailer body, constructed as a tubular stressed skin monocoque, can withstand a buff load of 337,000 pounds. Collision posts are used in the TGV coach and are capable of resisting a 157,000-pound shear load at the bottom post connection. The truck-to-carbody attachment strength was specified to be 221,000 pounds in shear. This attachment strength is provided by folded steel frames in the articulation assembly. The underframes do not employ center sills but make use of substantial side sills which offer protection against side penetration in the event of an accident.

Because of the articulated design, break-in-two protection is considered above average.

Development Status

SNCF's revenue service operations with the TGV-PSE began in 1981.

The development status of the train is classified as an operational production model, with 97 trainsets currently in revenue service.

Americanization

The TGV-PSE would require modifications in four of the five categories of concern.

Structure: The TGV-PSE locomotive was designed, built, and tested to meet UIC strength requirements but does not meet those specified in U.S. codes. The UIC codes call for a compressive strength of 200 metric tons (441,000 pounds) at the floor level; this is 26 percent below the 600,000-pound buff strength approved for the AEM-7 locomotive in its modification. It is noted, however, that there is a substantial collision structure ahead of the cab.

The collision posts in the coaches have a shear strength of 157,000 pounds at the bottom connection, while the compressive strength of the car is about 450,000 pounds.

Propulsion: The propulsion system would need to be modified for U.S. operations. This would involve removal of the 1,500 V dc propulsion control and the dc pantograph, since these are not required. Capability to operate at 11 kV, 25 Hz as well as 25 kV, 60 Hz would be needed.

Seating: The TGV has sufficient width to accept Amtrak-type 2-and-2 seating. Amtrak-type equivalent car arrangements are estimated to have both the end and intermediate cars seat 52 passengers, with room to seat 28 in the bar/coach.

Cab Signals: A cab signal or other protective system would be required to be compatible with whatever system is installed in the Pennsylvania Corridor.

Doors and Steps: The TGV may require modifications to the steps for loading at stations with high-level platforms. The steps built into the TGV are designed only for low-level platforms. Carbody floor height is approximately 10 inches lower than the existing high-level platforms found in the Philadelphia Corridor (e.e., Philadelphia and Lancaster). Accommodation to high-level platforms would require an extension to the door sill to bridge the gap between the relatively narrow carbody and the station platform edge. An external sliding plug door is used which covers an internal two-step well. If this well is left open within the vestibule, it could cause a tripping hazard. There is also a possibility that an external door, left open, could foul high-level platforms. An alternative would be to design the platforms to accommodate the TGV floor height.

Car Clearance: Because the TGV-PSE is designed to meet the restrictive UIC clearance requirements for interchange, it would probably meet all clearance restrictions imposed by the Pennsylvania Corridor.

Capital Cost

An estimated price of $4 million per TGV-PSE trainset was supplied by the manufacturer during the fall of 1977. This cost is for a 1-8-1 consist (i.e., locomotive, eight cars, locomotive). The estimate assumed an add-on to the first order for 87 trainsets, for 10 additional trains to be in service by June 1984. Modifications, tariffs and shipping costs are not included in the above estimate.

The price of a single TGV-PSE trainset in 1982 was 52.5 million French Francs.[7]

Inasmuch as the TGV-Atlantique (the trainset proposed for North American applications) will incorporate major propulsion system changes, the cost of a TGV train for Pennsylvania cannot be directly extrapolated from the original order. A cost of $11 million per trainset was used in the Alternative D estimate.

A.5 SERIES 961

Japanese National Railways has developed, tested and purchased several experimental, prototype and production modes of successively improved bullet trains. After the introduction of the original Series 0 bullet trains on the New Tokaido Line in 1964, development work centered on the Series 961 and 962 trainsets to obtain operating experience before proceeding with production of new equipment for the Tohoku and Joetsu Shinkansen.

The Series 961 most closely approximates the bullet train technology proposed for North American applications. It represents a second-generation high-speed train design for Japan; it was built in 1973 and subsequently modified as test experience dictated. It is geared for 162 mph and has a balance speed of about 186 mph on level, tangent track. It recorded a maximum speed of 198 mph on December 7, 1979, under special test conditions.

The production model, the Series 200, now operates on the Tohoku and Joetsu Shinkansen in 36 12-car trainsets. These cars incorporate the results of test experience gained with the 961 and 962. Beginning in March 1985, line service speeds of the Yamabiko trains on the Tohoku Shinkansen will be increased from 130 to 149 mph.[8]

The 961 is a six-car, electric multiple-unit trainset, made up of three pairs of cars, each having a different interior arrangement. The objective of this was to develop new seating, sleeping berth, and dining facilities before placing any of these designs into production. Train consists are based on a cab car and its mate at each end of the train with intermediate pairs of cars in between. The EMU concept was adopted early by JNR for the following reasons: Bidirectionality of the consists, better vehicle utilization, dynamic braking for all axles, propulsion redundancy and better wheel load distribution than obtainable from a locomotive-hauled trainset (to reduce track wear).

Each axle is powered and the traction motors on each pair of cars are connected as one eight-motor circuit. One transformer and rectifier set is located on one car of the pair. To improve propulsion control smoothness, a five-section, unequal-ratio, secondary transformer winding arrangement is used in conjunction with thyristors instead of the 25-tap cam controller used on the original bullet trains.

The brake system consists of dynamic braking (rheostatic) blended with air-operated disc brakes.

Carbodies are wide at 11 feet, thus providing space for 85 to 90 seats in a 2-and-3 arrangement.

Special Features

The most prominent feature of the Series 961 is the increase in performance over that of the previous fleet of bullet trains. This has been made possible by reducing the weight of the entire car as well as by increasing the capacity of the propulsion and braking systems. Acceleration remains constant from startup to approximately 110 mph before reaching the motor characteristics limitation.

Lightweight Construction: The carbody is a welded aluminum monocoque structure with side skirts extending to approximately eight inches above the rail for protection of underfloor equipment and for increasing carbody rigidity. In addition, carbody side entrance, side window, gangway diaphragm and so forth are of airtight construction to maintain the inside pressure of the car when passing through a tunnel. For this purpose, a continuous forced ventilation system was adopted which incorporates special fans for both fresh air intake and air exhaust.

Propulsion: One of the unique features of the Series 961 is the use of freon cooling for the thyristors. Evaporation of liquid freon in a closed system provides a highly efficient cooling mechanism for the semiconductors and also serves to eliminate air cooling system problems caused by by the intake of snow.

Truck Design: The truck arrangement is designed to accommodate the large 396 hp traction motors and two disc brakes per axle. A parallel drive is used in which the traction motors are mounted to the truck frame and thus are carried on the primary suspension, minimizing unsprung mass. The gear units are rubber-shock-mounted to the truck frame and coupled to the motors with flexible couplings. Concentric quill shafts connect the gear units to the axles.

Because of the size of the motors and gear units, the large disc brakes required for high-speed operation are mounted outboard of the wheels, between the wheels and the truck frame. This results in an unusually wide truck arrangement, which can be accommodated on the exclusive Shinkansen rights-of-way.

The truck frame is of fabricated steel with end and center transoms. Primary suspension is by coil springs with direct-acting hydraulic shock absorbers. Journal boxes are located by leaf springs. A separate nonrotating bolster is used, which rests on the truck frame through a center pivot and side bearings. Air springs between the bolster and carbody form the secondary suspension. Longitudinal radius rods are used to transmit traction forces.

Passenger Appeal

The appearance of the bullet trains in service in Japan is intended to convey the impression of speed. Various designs proposed for applications within the U.S. (NEC, California, Florida) present different external lines in each case. Inside the JNR cars the appearance is one of neatness and efficiency; the wide carbodies contribute to a sense of spaciousness despite 3-and-2-across seating in second-class cars.

Two-and-2-across seating using Amtrak-type seating would provide space that is nearly the same as that of the Amfleet car. The carbody width of a North American bullet train would probably have to be somewhat narrower than that of the JNR standard in order to satisfy existing clearance restrictions, resulting in an interior width more similar to Amfleet equipment. Other interior features such as the placement of air conditioning evaporator blowers overhead result in a cross-sectional shape of the passenger compartment which would be similar to an Amcoach except that the inward slope of the sides is less pronounced for the 961.

Side windows are closely comparable with those of Amfleet equipment. Windows are individual rather than paired, but the window area is approximately the same.

Placement of the toilet facilities in one car of each pair as on the 961 would be less convenient than on the Amfleet cars. However, this could be changed.

Passenger Comfort

Ride Quality: The only data available on the ride quality of the Series 961 indicates that the specified vibration levels are mostly JNR's Category 1.[9]

Interior Noise: JNR specifies a maximum value of 75 dB(A) for the noise levels of passenger and crew compartments when the train is operating. Assuming a linear reduction in noise level down to a value of 60 dB(A) at 20 mph or below, the predicted noise level of the Series 961 was 67 to 71 dB(A) in the speed range of 80 to 120 mph. If the train is operated in areas having wayside noise barriers similar to the ones that JNR has installed along the Tohoku Shinkansen, additional acoustic insulation will have to be installed in the car to protect against the wheel/rail noise being redirected on the carbody by the sound barriers.

Environmental Conditioning: Heating and air conditioning for the Series 961 are designed for operation in the colder northern areas of Japan where heavy snow is encountered. An overhead air conditioning arrangement is used in a manner similar to Amtrak practice in that two separate cooling systems are used with a blower unit at each end of the car. A total of 25 kW of heating and 15 tons of cooling are provided.

Compared with the Amfleet cars, the Series 961 has an equivalent cooling capacity but less than half of the required heating. An increase to approximately 60 kW of heat would be required for service in the United States.

Operational Safety

Passenger and Crew Safety: Flame-resistant materials are used for such components as interior carbody lining panels, seats and curtains. Standard portable fire extinguishers are provided, three in each car, which is an adequate number. Smoke detectors are provided in the dining cars.

The cars are equipped with a friction disc brake and a conventional dynamic braking system. At speeds of about 100 mph, the dynamic brake is capable of a retardation of 1.08 miles per hour per second (mphps). In emergency applications, a rate of 1.75 mphps is obtained. The dynamic brake is effective at speeds above 15.6 mph while the friction brake alone is used at lower speed. Above 15.6 mph, there is a blend of air and dynamic brakes. This system is adequate for Shinkansen service and has been used since the Series 0 cars were introduced in 1964.

For economic and safety reasons, the window area has been reduced in size from that of the Series 0 cars. This new design, which calls for a width of 26 inches and a height of 17 inches, is below the maximum Amtrak window size criteria. The glazing material is tempered glass which would require replacement with a nonbreakable material for train operations in the United States.

The doors are of the sliding panel type. Each car is equipped with a zero-speed relay circuit to prevent operation of the train with any door open, as well as to keep all doors from opening until the train stops. Emergency egress may be made through emergency exit door in each car.

The Series 961 is equipped with a fully automated train control system with five-aspect cab signals having a digital readout mounted on the instrument panel directly in front of the engineman. Although highly reliable, it would probably require complete replacement, or at least major modification, for it to be made compatible with U.S. track signal circuits.

Crashworthiness: Unlike the earlier Series 0 cars which are built of steel, the 961 is of welded aluminum alloy construction with an aluminum underframe. The cars weigh approximately 65 tons.

The Series 961 cars do not meet federal buff strength requirements for structural integrity under an 800,000-pound compressive load because they are designed to meet the JNR standard of approximately 220,000 pounds. (U.S. self-propelled passenger cars must meet passenger locomotive structural requirements.) The Series 961 cars do not have collision posts or other structure across the ends to resist penetration.

The 961 cars are equipped with hook-type couplers which are inadequate to satisfy federal anticlimbing requirements.

Development Status

Japanese National Railways began bullet train operations in 1964. Since the opening of the original Tokaido Shinkansen, JNR has extended operations on that line to Hakata (Sanyo Shinkansen) and constructed two new Bullet Train lines north of

Tokyo (Joetsu and Tohoku Shankansen). The trains operating on the newest line are the Series 200 trainsets, derived from the Series 961.

Although the development status of the Series 961 is classified as a prototype, its derivative, the Series 200 trainset is classified as an operational production model with 432 cars in or entering service. Both trains employ conventional, reliable technology.

Americanization

The Series 961 would require changes in all of the areas of concern.

Structure: The most deficient feature of the Series 961 is the buff strength of 220,000 pounds, which meets JNR standards for Shinkansen operations. No collision post structures are provided. (However, previous technical specifications prepared by JNR for an Americanized version of a 961/962, modified for Northeast Corridor applications, state that AAR buff load requirements can be met.)

Modification will require extensive reinforcement of the carbodies, particularly in the area of the draft gear. Anticlimbing and antitelescoping provisions must be added, along with stronger couplers. The design draft strength of the present 961 coupler is 353,000 pounds and the compressive strength is 661,000 pounds.

Propulsion: The propulsion system is designed for 25 kV, 50 and 60 Hz operation and therefore is suitable if 25 kV, 60 Hz electrification for the corridor is selected. Voltage change provisions would be required for use with 11 kV, 25 Hz.

Seating: Because of the width of the car in JNR service, a coach capacity of between 85 and 90 seats, using 2-and-3-across seating, can be obtained. A car built to meet the car construction outline recommended by AAR for interchange service could easily accommodate 2-and-2 seating using standard Amtrak seating. The Amtrak equivalent car arrangements are estimated to provide 52 seats in the cab coaches, 76 seats in intermediate coaches, and 56 seats in a snack bar/coach.

Cab Signals: A cab signal or other protective system would be required that is compatible with whatever system is installed in the Pennsylvania Corridor.

Doors and Steps: Sliding side doors are used with no step provisions and car floor height is compatible with the existing high platforms in Philadelphia.

Car Clearance: In its present form, the Series 961 will not meet the existing clearance restrictions established by the AAR car construction outline for cars used in interchange service. The Japanese Association of Rolling Stock Manufacturers has proposed a narrowed version of the Series 961 for Amtrak use on the NEC. The disc brake on the Series 961 is located outboard of the wheel. The overall clearance is even less because the carbody skirt extends downward on the outside of the truck to provide acoustic and aerodynamic benefits. Clearance modifications would require further investigation in later stages of the project.

Capital Cost

Prices for Series 961 trainsets are not available because the train has never been placed into production. The Series 200 cars, which are a production derivative of the 961/962 series, were reported to have cost 130 billion yen for 432 cars in 1982.[10] At roughly 251 yen per dollar, this gives a price of $1.2 million per car in 1982.

A price of $800,000 per average car of the original bullet train was quoted by the Japan Association of Rolling Stock Industries in August 1976.[11] Inflation from August 1976 to January 1984 would raise this estimate to $1.25 million per car.

The above prices do not include the assumed modifications, spares, shipping and tariffs.

A.6 WEST GERMAN IC-E TRAIN

Deutsche Bundesbahn (DB) is in the midst of a railway improvement program known as the Intercity Program. The program has two parts: the improvement of existing services through minor investments, and the development of a high-speed service through the application of known railway technology, and the construction of high-speed connector lines.

DB is rebuilding its rail infrastructure from that of an east-west network (which served between its western cities and Berlin before World War II) to a north-south network. New lines are being designed to handle passengers by day and freight by night.

Present sections of its main lines permit passenger train speeds of 137 mph; this will be raised to 155 mph on the new lines under construction, and probably higher in the future. Beginning in 1974, sections of new lines between Hamburg/Frankfurt/Munich and Bremen/Hanover/Munich were started. Minimum curve radius on new IC lines is 23,000 ft, grades are restricted to 1.25 percent, about 30 percent of the network will be in tunnels, and maximum speeds of 155 mph will be permitted.

The IC-E is the equipment under development for operation on these premium lines. Some consideration has been given to pooling TGV/IC-E service, and there have been studies, including Paris/Brussels/Cologne, and Paris/Frankfurt interchange service for IC-E and TGV.

Special Features

The trainset is designed to provide 400 passenger seats in six cars. The four-axle power cars (locomotives) will have the same ratings as the E120 (5.6-MW each) with a unit at each end of the train, with the pair operating in the pull and push mode.

The locomotives will use Brown Boveri's three-phase traction motor design to effect energy savings.[12] The traction motors will be mounted to a carbody bolster with gearboxes suspended from the truck frame by a swing hanger arrangement.

Aluminum extrusions are being used to obtain a modular concept in the design of the cars, allowing DB to convert a car from a first-class "saloon," to a second-class compartment car, to a second-class "saloon," all overnight. This was referred to as the "multi-class concept" which should permit easier coach refurbishment by DB.

Locomotives will have a diagnostic capability to include train systems, brakes, and electrical supply. Car diagnostics will include brakes, electrical system, and trucks.

Development Status

The development work is sponsored by the Research Ministry (BMFT) and DB is the project manager; Krupp, Siemens and MBB are the principal contractors. Krupp has responsibility for the power cars, Siemens for the electrical propulsion and MBB for cars. Krauss-Maffei and Thyssen Henschel are also heavily involved in the locomotive development work. The objective is to demonstrate the IC-E prototype on DB's 150th anniversary in December 1985.

Capital Cost

A total of DM 72 million (Deutsche Marks) was quoted as the cost for the IC-E; it is not clear whether this is the investment or projected purchase price.[13]

References

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13 Briefing by Dipl.-Ing. Kuhla of Deutsche Bundesbahn, May 26, 1984, Munich, West Germany.

APPENDIX B
MAGNETIC LEVITATION

Magnetic levitation, or suspension, is a method of using magnetic forces to support a vehicle without any physical contact between it and the ground. We know that magnets can exert forces at a distance. Opposite poles attract; like poles repel, as shown in Figure B-1.

This principle has been applied in various ways to lift, guide and propel vehicles at high speeds. The designation "flying train" is used to suggest that magnetic levitation combines the best features of the airplane with the best features of a train. The ability to float without touching the ground permits a smooth ride at very high speeds, 300 mph and more, without the noise, friction, wear, high maintenance cost and danger of derailment of railroads. Yet the advantages of a train are retained—high passenger capacity, frequent, reliable schedules, access to the central city, better service to intermediate destinations, and low sensitivity to adverse weather conditions (fog, rain, snow).

This appendix describes two different Maglev concepts under active development in Japan and West Germany. The features of each system are discussed individually, and then the two approaches are compared and contrasted in a concluding discussion.

B.1 JAPANESE REPULSION MAGLEV

The advanced high-speed ground transportation technology selected by the Japanese Ministry of Transportation is the magnetic repulsion levitation or electrodynamic system, often designated EDS. It is based on the principle that when a magnet moves over a conductor, eddy currents are induced in the conductor and these interact with the magnet to produce a repulsive force. That is, the magnet is pushed away from the conductor. In the simplest case, a permanent magnet moving over a perfectly conducting plate, as shown in Figure B-2, the magnet acts as if there were a mirror image of the magnet (shown dashed) reflected in the upper surface of the plate. Since like poles repel, the force is repulsive. By attaching a number of strong magnets to the underside of a vehicle, it can be made to levitate over a track or guideway consisting of conductors. Perfect conductors do in fact exist, called "superconductors." However, superconductivity occurs only at temperatures near absolute zero. In constructing a transportation system, it is not desirable to supercool the entire length of guideway. Practical designs for a repulsive Maglev employ normal conductors like copper or aluminum, which do have some resistance to the flow of electric currents. This resistance has three effects:

- o No force is developed when the vehicle magnet is not moving. In fact, insufficient repulsive force is developed to support the vehicle until it reaches an appreciable speed, typically 50 to 60 mph. So like an airplane, the repulsion Maglev vehicle requires wheels until it "takes off," or floats.

- o The eddy currents induced in the guideway conductor dissipate energy and exert a drag force, in addition to the lift force on the vehicle. This drag force must be overcome by the propulsion system which drives the vehicle

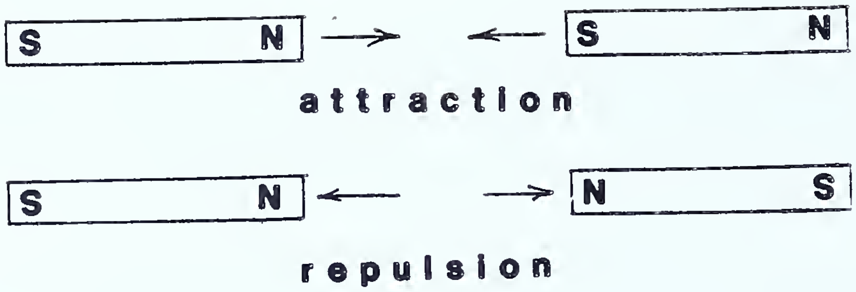

FIGURE B-1 MAGNETIC FORCES

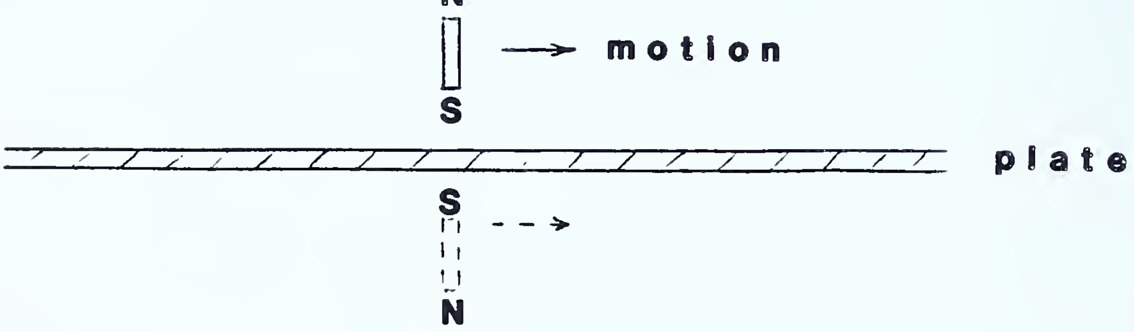

FIGURE B-2 REPULSION CONCEPT

forward. Below the takeoff speed, the drag force is large, and a major fraction of the total propulsion force must be devoted to overcoming it. Above 200 mph, the magnetic drag force is a minor fraction of the aerodynamic drag force on the vehicle.

- The propulsion power required to overcome magnetic drag does not depend much on speed. The faster the vehicle moves, the less time spent in reaching its destination; therefore, less energy is consumed in levitating the vehicle.

Japanese National Railroad (JNR) engineers have taken account of these factors in optimizing the design of their Maglev vehicle and guideway. To reduce drag, they use copper wound coils rather than aluminum plate for their guideway conductors. This reduces the eddy currents and the corresponding energy dissipation. However, the lift force is thereby diminished, so more powerful magnets must be used on the vehicle. Superconducting electromagnets (SCM) are used on the vehicle because they can produce extremely strong magnetic fields without electric power. (They must, however, be maintained at temperatures within a few degrees of absolute zero by circulating liquid helium.) With superconducting magnets, the vehicle can float several inches above the guideway, thus minimizing the effect of guideway irregularities or water, snow, ice and debris.

These high-speed Maglev vehicles, in addition to being levitated, must also be constrained to follow the guideway. Lateral guidance is provided in a similar manner to levitation. Vertical conductors are placed on each side of the horizontal conductors to form a U-shaped or channel guideway. Finally, a propulsion system is required to drive the vehicle to high speed. Clearly, conventional wheel traction is inappropriate for a vehicle that does not contact the ground. A linear motor that imparts force to the vehicle by magnetic means is the solution. The Japanese use a linear synchronous motor whose primary windings are embedded in the surface of the guideway, obviating the need for wayside power collection (catenary, third rail etc.). These three-phase windings generate a travelling magnetic wave that interacts with the SCMs on the vehicle to carry them along in analogy to a surfboard on an ocean wave. In the Japanese system, then, each SCM functions to provide lift and guidance and to act as the "rotor" of the motor.

SCMs permit gaps or clearances of 4" or more between vehicle and guideway whereas the gap for attraction is about 1/4 to 3/8". The claim is that the large gap is more tolerant of guideway irregularities, ice, snow and debris on the guideway, and as a result higher speeds are possible, perhaps up to 500 mph. Flat land is at such a premium in Japan that major new airports must be avoided at almost any cost. Therefore, high-speed ground transportation must be fast enough to discourage domestic air travel.

A cross sectional drawing of the Japanese National Railways MLU001 test vehicle and guideway is shown in Figures B-3 and B-4.[1] All the elements aforementioned are depicted. Figure B-5 shows the MLU001, a three-vehicle train running on the test track at Miyazaki in Kyushu. A single vehicle attained 250 mph in August of 1983, and in subsequent tests three-car couples are expected to reach 310 mph. (An earlier version designated ML500 reached a world speed record of 517 km/h (321 mph) in December 1979.) The three-car set has a total length of 93 ft, each car

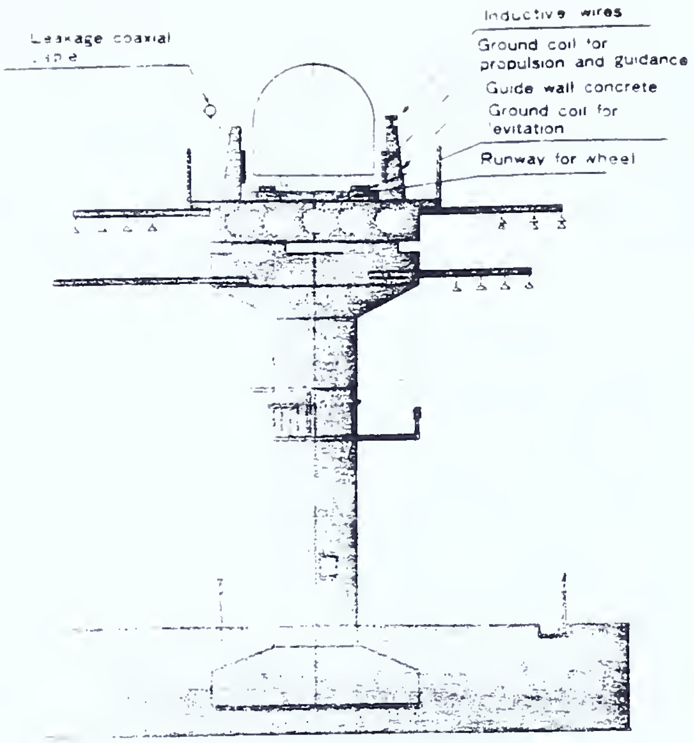

FIGURE B-3
VEHICLE/GUIDEWAY SECTION

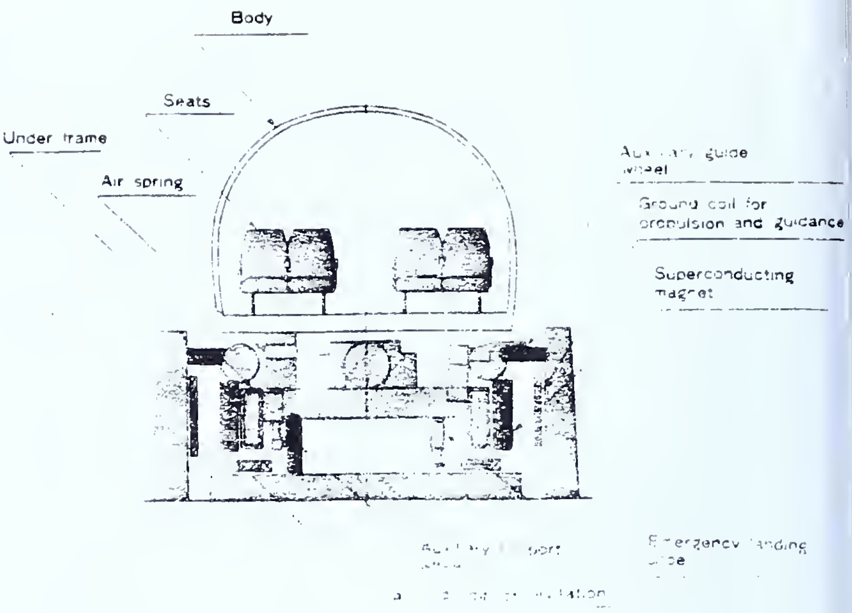

FIGURE B-4
MLU-001 VEHICLE SECTION

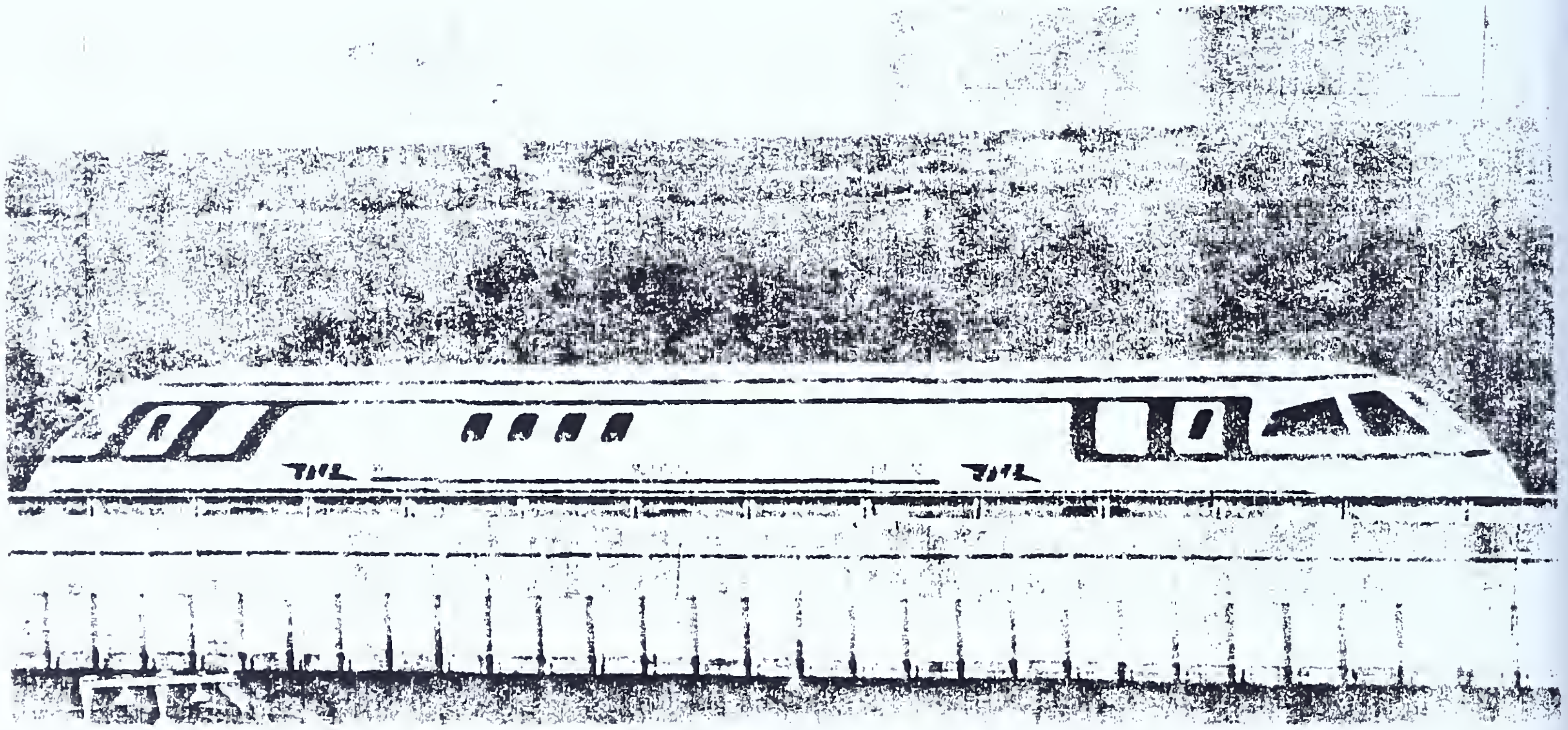

FIGURE B-5 THREE-CAR TEST TRAIN AT MIYAZAKI being 10 ft wide by 11 ft high and having a mass of 11 tons. The cars are described as being full scale in width and height, but half-scale in length and mass. The train has 32 seats, and high-speed runs have been conducted with passengers aboard.

Thus far, JNR and the Japanese Ministry of Transportation have expended about $120 million in research and development of Maglev.[2] In the process, Japan has made enormous advances in cryogenics and superconducting magnet technology, which will have commercial applications regardless of whether a Maglev system is ever built.[3] The helium temperature refrigerator used aboard the Maglev vehicle removes 5W of heat and weighs only 88 lbs,[4] and smaller Stirling cycle and Gifford McMahon cycle refrigerators are undergoing on-board tests.[5]

Cryostats, which thermally insulate the magnets while transmitting tons of varying forces to the low temperature environment, also represent a major and unexpected advance in cryogenics. Also, the linear synchronous motor with superconducting secondary winding represents a major achievement in superconducting motor-generator technology. As a result of this transportation research, the Japanese have taken the lead in three technologies for which Japan was recently a U.S. customer.

JNR has proposed a prototype Maglev train and a 25-mile track, which would ultimately be part of a revenue system. This development is expected to cost about $2 billion to be financed by the Ministry of Transport, which so far has not made a decision. Details on the prototype design are sparse, but a system synthesis has been performed by JNR for a 310-mile route with one intermediate stop (presumably Tokyo-Nagoya-Osaka).[6]

A 10-car, 800-seat train making the trip in 83 minutes at a cruise speed of 250 mph is expected to consume 34.5 MWh of energy. Of this, about 25 MWh is needed to overcome aerodynamic drag, 6 MWh to overcome magnetic drag (lift/drag = 100), 2.1 MWh for SCM refrigeration and 1.4 MWh for hotel power.[7] JNR estimates that the cost of double-track Maglev guideway will be 100 percent to 120 percent of the cost of high-speed rail. Based on the recently completed Tohoku and Joetsu lines, the latter cost is about $30 million/mile in 1979 prices.[8] This cost includes extensive tunneling (40 percent of the 168-mile Joetsu line) and countermeasures for snow and noise. However, operating costs (aside from energy), are expected to be less than half that of the Shinkansen because there are no moving parts in contact.[9] Increasing the maximum cruise speed to 310 mph increases the energy consumption to 48 MWh, but reduces the trip time by only seven minutes. The problem is that at high speed, unlike an airplane, the Maglev train must push its way through sea-level air which causes severe drag, especially in tunnels. And at low speeds, unlike wheeled trains, it must expend large amounts of power to levitate itself. Also the LSM with its large gap and reactive currents is perhaps only 65 percent as efficient as the dc traction motor used in the Shinkansen. The earliest implementation of a revenue Maglev system in Japan is reported to be in the early 1990s.[10]

The primary reason given by JNR for preferring the electrodynamic concept seems to involve safety--its intrinsic stability (no need for servo control) and the U-shaped guideway which captures the train in event of a levitation or guidance failure. Considering that a 300-mph vehicle has enough kinetic energy to fly 3000 feet upward, the guideway must be strong enough to contain the train in an emergency situation.

The linear synchronous motor by its very nature cannot allow a speed differential between adjacent trains. If a train should get out of synchronism with the track currents, it would be instantly detected, initiating a programmed slow-down in adjacent track sections. Because speed is controlled from the track rather than the train, the trains are automatically coordinated rather than being autonomous.

B.2 WEST GERMAN ATTRACTION MAGLEV

The attraction Maglev concept selected by the West German Ministry of Research & Technology (BMFT) is perhaps easier to grasp than the electrodynamic repulsion system. It is designated the electromagnetic system or EMS. Electromagnets attached to the vehicle are attracted upward by steel rails which form the guideway. Because the force increases rapidly as the gap between magnet and rail diminishes, there is an unstable tendency for the magnets to clamp to the rail or alternately to fall away. This tendency is overcome by a servo control aboard the vehicle, which swiftly reduces the magnet current if the ½-in gap between rail and magnet narrows and increases the current if the gap widens. Separate sets of iron core electromagnets are employed to lift and guide the vehicle. However, the lift magnets perform a dual role as the "rotor" of a linear synchronous motor whose iron-cored long stator is embedded in the guideway. The functioning is similar to the Japanese LSM already described. Again, the objective of the long stator LSM is to be compatible with the non-contacting suspension, avoiding a "third" rail or catenary. Figure B-6 shows a cross section of the vehicle and guideway,[11] while Figure B-7 shows a model of the prototype TR-06 train. This system was developed by Transrapid-EMS of Munich using Federal funds. The two-car train is 178 ft long, 12.2 ft high, 12.1 ft wide and has a mass of 112 tons. The guideway is a 20-mile loop of which 13.4 miles are now completed.[12] The TR-06 is closer to a practical revenue transportation system than the Japanese MLU001, which is a research vehicle. Transrapid claims its high-speed Maglev guideway will cost no more than present day wheel-on-rail infrastructure.

The purpose of the Emsland facility is to subject the TR-06 to endurance tests at speeds of up to 250 mph, to identify and remedy any design deficiencies and to refine the design of vehicle and guideway for revenue operation. By the end of October 1984, preliminary tests and modifications are expected to be completed with the system ready to be turned over to Lufthansa (the national airline), DB (the national railroad), and an independent testing organization for one year of endurance testing. If no design deficiencies are discovered in the TR-06 vehicle or guideway, the technology could be ready for a revenue system in early 1987.[13] Realistically, problems will occur and must be solved; 1988 is a more likely implementation date.

Transrapid claims seating comfort superior to air coach and Amtrak; however, seating is European style (face to face). There is no foot room or reclining seat back. American standards of comfort may require reducing seating capacity by 10 percent to 20 percent, which would increase per-passenger costs.

Safety is a paramount concern. Clearly the vehicle must not escape its guideway. This is the reason for the "caged" arrangement of the underbody around

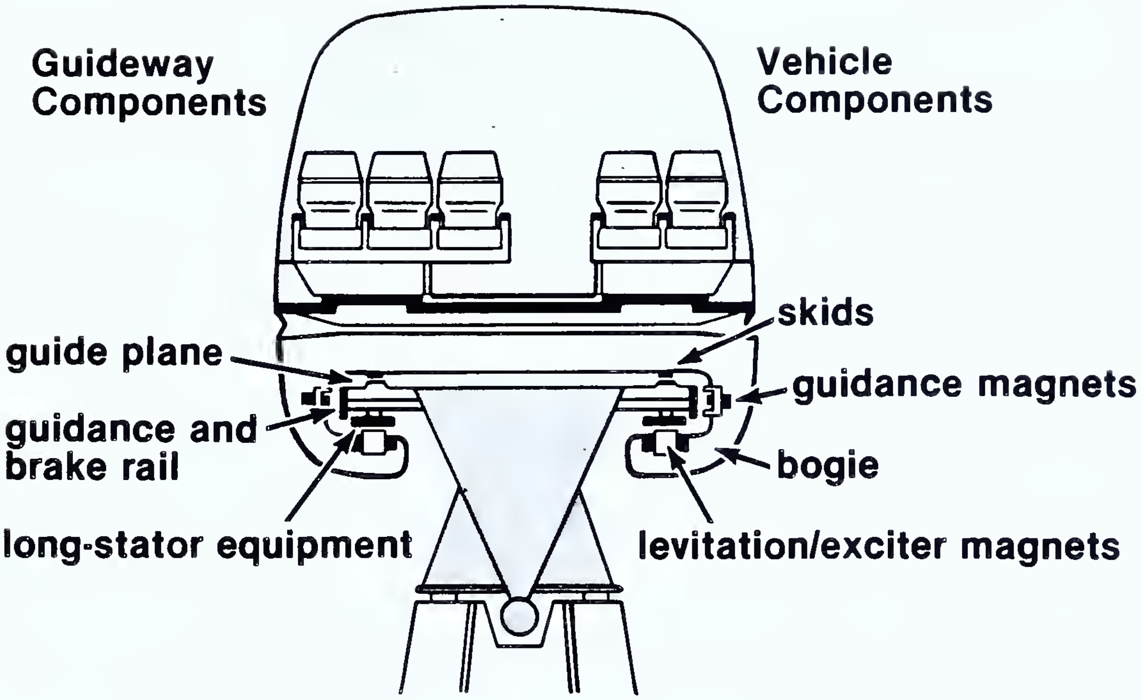

FIGURE B-6 TR-06 VEHICLE/GUIDEWAY CROSS-SECTION

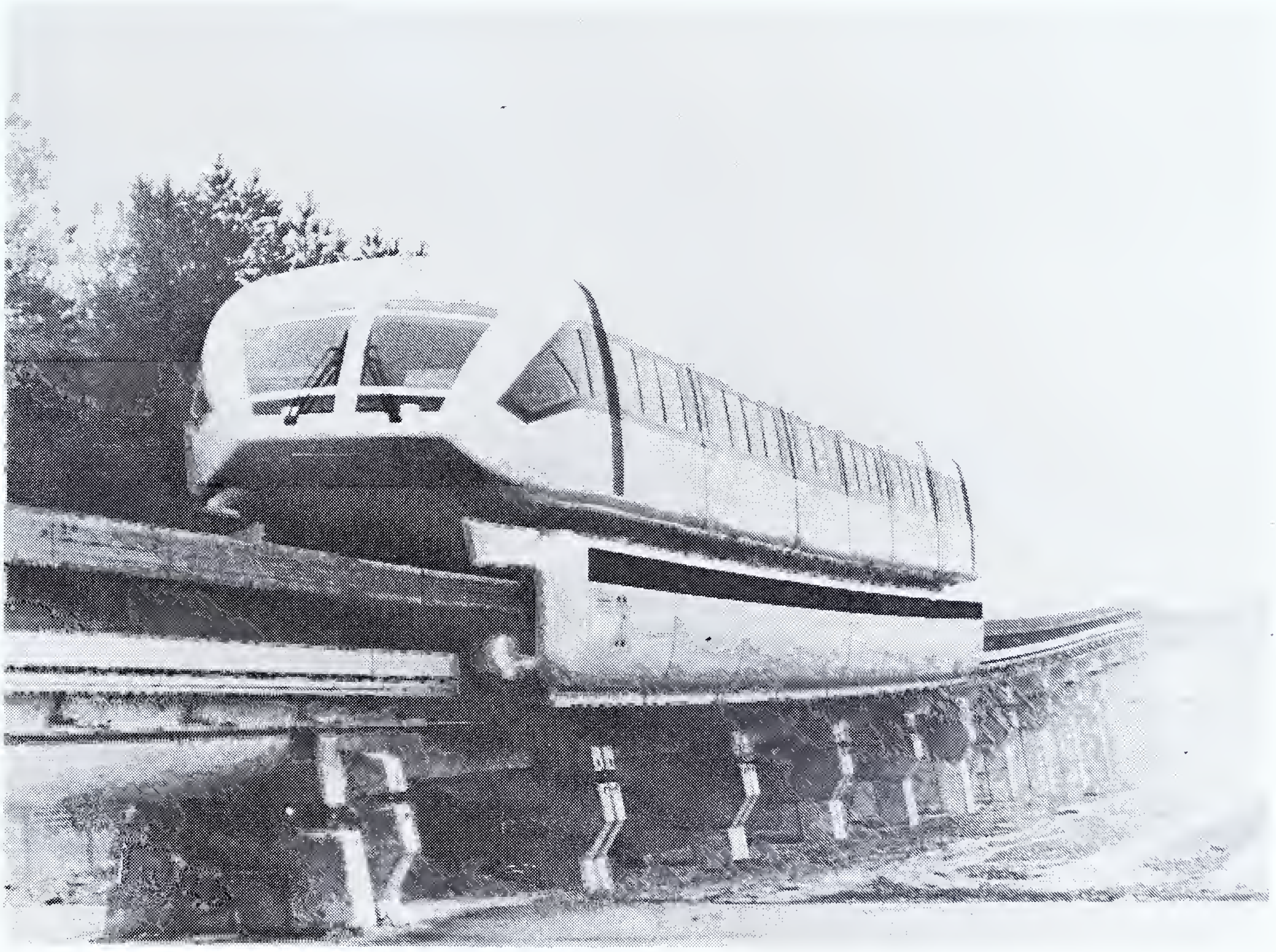

FIGURE B-7 TR-06 VEHICLE/GUIDEWAY

the track. In case the magnets or servo control fails, the vehicle lands on skids and is brought to a rapid but smooth stop by friction. An important outcome of the test program is to determine how well this emergency system works. Normal braking is by means of magnetic forces from the long stator motor. In addition, mechanical brakes can function while the vehicle is levitated.

At the present stage of development, it seems unlikely that any fundamental flaws remain to be found. The principal risks appear to be related to reliability and cost, which are the targets of the Emsland test.

Between 1970 and 1980, BMFT provided DM450 million (about $200 million) in support for high-speed ground transportation research and development. This is in addition to substantial contributions by the companies that performed the work. The Emsland Test Facility has been appropriated DM 280 million so far.[14] Perhaps the most important fallout from this work is the development of power conditioning units (PCUs) of unprecendented power-handling capabilities, 20 to 35 MVA.[15] These PCUs have applications in conventional railway locomotives as well as in industry.

The reasons given by German authorities for rejecting repulsion Maglev are complexity, cost and development time of reliable cryostats, refrigerators and SCMs; and the extra energy consumption due to magnetic drag.

B.3 DIFFERENCES BETWEEN THE GERMAN AND JAPANESE MAGLEV CONCEPTS

- The German plan calls for four- to six-car trains carrying 400 to 610 passengers, while the Japanese plan is for 10- to 20-car trains. The reason for this is the Japanese expect much higher traffic volumes such as are experienced on the Shinkansen, 125 million passenger/year in 1982, up to one million passengers on a peak day. With an active track, trains cannot be lengthened without replacing the trackside electrification system, so the system capacity is locked in. By employing short trains, the Germans save on electrification cost, but they thereby severely limit the capacity of the route.

- The Germans and Japanese have chosen very different technologies for similar tasks. The Germans, having tested air cushion, attraction and repulsion Maglev vehicles, are focusing all their development effort on attraction Maglev because:[16]

    1. Air cushions are noisy and have high maintenance and energy consumption.

    2. Attraction Maglev requires no significant advance in the state of the art (except PCUs).

    3. The SCMs must be continuously maintained at cryogenic temperature.

    4. Repulsion Maglev entails the cost, delay and uncertainty of developing refrigerators, cryostats and SCMs which must be made many times more efficient and reliable than possible with present technology.

The Japanese have tested both attraction and repulsion Maglev at low speed, but favor repulsion at high speeds because:

1. Repulsion is intrinsically stable, unlike attraction which requires servo control of magnet current to avoid clamping of the magnet to the rail.
2. SCMs permit clearances of 4" or more between vehicle and guideway, whereas the gap for attraction is about 1/4 to 3/8". The claim is that the larger gap is more tolerant of guideway irregularities, ice, snow and debris on the guideway, and as a result higher speeds are possible, up to perhaps 500 mph.
3. At speeds above 250 mph, aerodynamic drag dominates magnetic drag so the latter is not an important factor.
4. The greater field strength and longer poles of the SCMs make for a more efficient and less costly long stator linear synchronous motor than with the iron-cored attraction levitation electromagnets.
5. Numerous tunnels are required in the mountainous terrain and densely populated areas of Japan. The sudden shock wave transient encountered in entering a tunnel is believed by Japanese engineers to be capable of overwhelming the servo control of the attraction Maglev.

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APPENDIX C
TAX LAW CONSIDERATIONS

C.1 AVAILABILITY OF TAX-EXEMPT FINANCING

C.1.1 Appropriate State Legislation

Bonds, issued by a governmental unit, which are used to finance operations of a privately-owned business are generally classified as Industrial Development Bonds (IDBs). Even though issued by a governmental unit, IDBs will not be tax-exempt unless they satisfy certain Internal Revenue Code rules discussed below.

IDB financing for a Pennsylvania HSR system requires a state enabling statute that applies to this type of project. The Pennsylvania Industrial and Commercial Development Authority Law[1] does not directly deal with rail systems but should permit parts of the system to be financed.

C.1.2 Availability of Federal Exemption

Whether there is an available federal tax exemption for IDBs to finance this kind of facility or, failing that, whether tax-exempt bonds that are not IDBs can be used is open to question.

IDB Requirements

There is no clear statutory authority for the use of tax-exempt IDB financing for an HSR corridor. The qualification of IDBs as tax-exempt obligations depends on compliance with particular statutory exemptions under Code section 103(b). IDBs, absent an exemption, are not tax-exempt obligations. There are two possible exemptions under Code section 103(b)(4) which could be used:

(a) Code section 103(b)(4)(D) which permits the financing of "mass commuting facilities" and parking facilities, and

(b) Code section 103(b)(4)(I) which permits the financing of "qualified mass commuting vehicles" as defined in Code section 103(b)(9). Obligations issued after December 31, 1984 to finance such vehicles, however, will not be tax-exempt, unless this statutory provision is amended or extended.

A mass commuting facility is defined in Reg. Section 1.103-8(e)(2)(iv) to include real property, together with improvements and personal property used therein, such as machinery, equipment and furniture, serving the general public commuting on a day-to-day basis by bus, subway, rail, ferry or other conveyance which moves over prescribed routes. The term also includes terminals and facilities that are functionally related and subordinate to such a facility, such as a parking garage, car barn or repair shop. The regulations state that the use of mass commuting facilities by noncommuters in common with commuters is immaterial. For example, according to the regulations, "a terminal leased to a common carrier bus line which services both commuters and long-distance travelers would qualify as an exempt facility."

However, a system which is primarily designed for long-distance travel as opposed to commuting may not qualify. It would be necessary at minimum to get a ruling from the IRS on the applicability of a financing for part of a system which served both area commuters and long distance travelers. An attempt to classify an HSR system with only a few stops across the state as a mass commuting facility could be subject to attack.

The limited exemption for "qualifying mass commuting vehicles" was enacted as part of the Economic Recovery Tax Act of 1981. A qualified mass commuting vehicle under proposed Treas. Reg. Section 1.103-8(j)(2) is defined to be any bus, subway car, rail car or similar equipment (1) leased to a mass transit system wholly-owned by one or more government units or agencies or instrumentalities of a governmental unit, and (2) used by the mass transit system in providing mass commuting service. "Mass commuting services" are defined as a transportation system, if used predominantly by business commuters on a day-to-day basis. The definition specifically excludes a sightseeing service. Thus, the mass commuting vehicle provision will not be available unless the wholly-government-owner test and the commuter test are both satisfied.

Effect of Tax-Exempt IDB Financing on Tax Benefits Available to the Owner of the Property

Under current law, the use of IDB financing generally allows the cost of bond-financed property to be recovered over the shortened accelerated cost recovery system periods (three, five, 10 or 18 years),[2] but does not permit the use of an accelerated method within those periods. Therefore the full benefit of rapid depreciation under the accelerated cost recovery system is lost for property financed with IDBs.

Under current law the investment tax credit[3] would be available for qualified property even though financed with IDBs.

Under recently-enacted legislation concerning government leasing, the use of tax-exempt financing will result in longer depreciation or recovery periods and disallowance of the investment tax credit if the property otherwise is treated as "tax-exempt use" property. IDB financing alone will not have this result under the legislation. This subject is discussed in more detail in Section C.2 of this appendix.

C.1.3 Other Tax-Exempt Financing

If IDBs are unavailable, the question then becomes whether state or other municipal debt can be used. Municipal debt, for example, could be issued to provide construction financing for the HSR system and acquisition of the various components. This initial arrangement could then be followed by a sale and leaseback to private equity investors,[4] or the investors could lease the property to another governmental agency or provide the equipment under a service contract to another agency. These arrangements, contemplating as they do private ownership following public financing, raise the question of whether the tax exemption for the original municipal bonds will be lost. If those bonds become IDBs, the interest on the bonds will not be tax-exempt unless an exemption is available.

Unfortunately, the statute and regulations define IDBs broadly. An IDB is an obligation (1) of which all or a major portion (25 percent) of its proceeds are to be used directly or indirectly in any trade or business carried on by any person who is not an exempt person (the "trade or business" test) and (2) the payment of the principal or interest of which is in whole or in major part secured by an interest in the property (or payments in respect of property) used or to be used in the trade or business (the "security interest" test). The "trade or business" requirement is satisfied if the bond proceeds are used to construct facilities to be leased or sold to private business users. Under the security interest test, the nature of the security for the source of the payment of the principal or interest on the bond issue may result in the bonds being treated as IDBs. The regulations in this area provide that a pledge of the full faith and credit of a state or governmental unit will not prevent a debt obligation from being an IDB if it otherwise satisfies the security test. For example, if the payment of the debt service on the bonds is secured both by a pledge of state revenues and an interest in the property used or to be used in a trade or business, the bond would be an IDB.

Whether the municipal debt and the private equity investment can be structured so that the IDB characterization can be avoided is unclear, but it is conceivable that such a structure can be achieved.

C.2 AVAILABLE TAX BENEFITS FROM OWNERSHIP OF ASSETS OF THE SYSTEM DURING OPERATION

C.2.1 General

If taxable investors own the property in the HSR system, depreciation (under the ACRS system) and ITC should be available once the assets are placed in service (i.e., once the service is in operation). As mentioned above, accelerated depreciation is not available if IDB financing is used. ITC will be disallowed and extended depreciation periods required if the property is used by or leased to any governmental unit or certain tax-exempt organizations.

Therefore, the financing and use of the property will have an impact on the availability of tax benefits, particularly for the personal property portions of the HSR system. There may be a significant problem of governmental use in situations where the governmental agencies want to control the providing of rail service. The leasing of property (e.g., rail cars) to governmental agencies or authorities would eliminate the investment tax credit, and require the use of extended depreciation periods and, therefore, service contract arrangements might be required.

In addition, current federal tax law will require the use of multiple types of limited partnerships composed of different groups of investors in order to maximize tax benefits. For example, because noncorporate lessors are generally unable to take advantage of the investment tax credit for such leveraged personal property as equipment, it would be necessary to attract corporate investors. Qualified corporations for this purpose do not include closely-held corporations or personal holding companies.

C.2.2 Recent Legislation

Several bills to reduce federal income tax benefits associated with properties leased or used by governmental or nonprofit organizations were introduced in Congress in 1983. This legislation (H.R. 4170) was signed by the President on July 18, 1984.

Under this legislation, ACRS deductions and ITC are eliminated or reduced with regard to property that constitutes "tax-exempt use" property. Personal property will be covered by these provisions if it is owned by, leased to or otherwise used by a tax-exempt entity, subject to certain exceptions and modifications. In the case of real property, a disqualified tax-exempt use will occur if one of the following circumstances exists:

(1) all or part of the property was financed with the proceeds of tax-exempt bonds and the tax-exempt entity using the property (or a related entity) participated in the financing;

(2) a tax-exempt entity (including a government unit) leases the property under a lease with a term exceeding 20 years or the lease contains certain fixed or determinable price purchase or sale options; or

(3) the use is pursuant to a sale/leaseback transaction.

It is significant that property leased to or used by a taxable organization that is established by a governmental entity will not be subject to these rules if a majority of the taxable subsidiary's board of directors is not appointed by a governmental entity. The possible organization of such entities, therefore, should be explored.

Generally, the legislation extends the recovery periods for tax-exempt use property, so that the annual allowances for depreciation will be reduced and the cost of the property will be required to be recovered over a greater number of years. In the case of 18-year real property the recovery period will be 40 years or 125 percent of the term of the lease, whichever is greater. The recovery period for all other property will be the midpoint life of the property under the prior asset depreciation range[5] depreciation rules or 100 percent of the term of the lease, whichever is greater. If property has no asset depreciation range, it will be treated as having a 12-year life. Certain broad classes of property are exempt from the depreciation rules; for example, computers and related peripheral equipment, high technology telecommunications equipment, and medical equipment.

The legislation does not answer definitively the question of whether service contracts are leases for tax purposes. The legislation describes a number of factors which must be taken into account. Factors that tend to indicate the existence of a disqualifying governmental use include: (1) the tax-exempt entity is in physical possession of the property, (2) the tax-exempt entity controls the property, and (3) the tax-exempt entity has significant possessory or economic interests in the property. Factors supporting the contrary conclusion are: (1) the service provider bears any risk of substantially diminished receipts or substantially increased expenditures if there is nonperformance under the contract, (2) the service provider uses the property concurrently to provide services to other entities unrelated to the tax-exempt entity, and (3) the total contract price substantially exceeds the rental value of the property for the contract.

Finally, the legislation contains a general exemption for mass commuting vehicles placed in service before January 1, 1988 or placed in service after that date pursuant to a binding contract entered into before April 1, 1983. Because of these dates, this exemption as well as the proposed transitional rules for the leasing legislation, probably will be of no benefit to the HSR system, even if the system's rail cars qualify as commuting vehicles.

In order to avoid the cutback in tax benefits described above, it will be necessary to use service contracts and/or arrangements with taxable subsidiaries of government units if the system is to be a mixed public/private operation.

Table C-1 summarizes the rules discussed above on tax benefits available to the owners of tangible personal property under prior law and under the new tax law.

TABLE C-1

SUMMARY OF TAX BENEFITS TO OWNERS OF PERSONAL PROPERTY

Type of Transaction	Prior Law		New Law	
	Depreciation	ITC	Depreciation	ITC
Lease to government unit with conventional financing	Full ACRS allowed	disallowed	ACRS disallowed (depreciation permitted over extended useful life periods)	disallowed
Lease to government unit with IDB financing	Reduced ACRS (straight-line depreciation over ACRS periods)	disallowed	ACRS disallowed (depreciation permitted over extended useful life periods)	disallowed
True service contract with government unit with conventional financing	Full ACRS allowed	allowed	Full ACRS allowed	allowed
True service contract with government unit with IDB financing	Reduced ACRS (straight-line depreciation over ACRS periods)	allowed	Reduced ACRS (straight-line depreciation over ACRS periods)	allowed but might be challenged if government unit that uses the property participated in the financing

References

1 73 Pa. Stat. Ann. Section 371-386 et seq.

2 The accelerated cost recovery system (ACRS) is a rapid depreciation system which became effective in 1981 and which permits taxpayers to write off assets over periods which are much shorter than the expected useful life of these assets.

3 The investment tax credit (ITC) is an allowance which can be used to offset federal income tax liability on a dollar for dollar basis. Generally speaking, the credit equals 10% of the cost of qualifying assets. Tangible property used in providing transportation services (other than land and buildings) generally qualifies for the credit.

4 Under recently-enacted tax legislation this would constitute "tax-exempt use property" reducing federal tax benefits otherwise available.

5 The asset depreciation range (ADR) system is a prior system for depreciation deductions replaced by the ACRS rules in 1981.

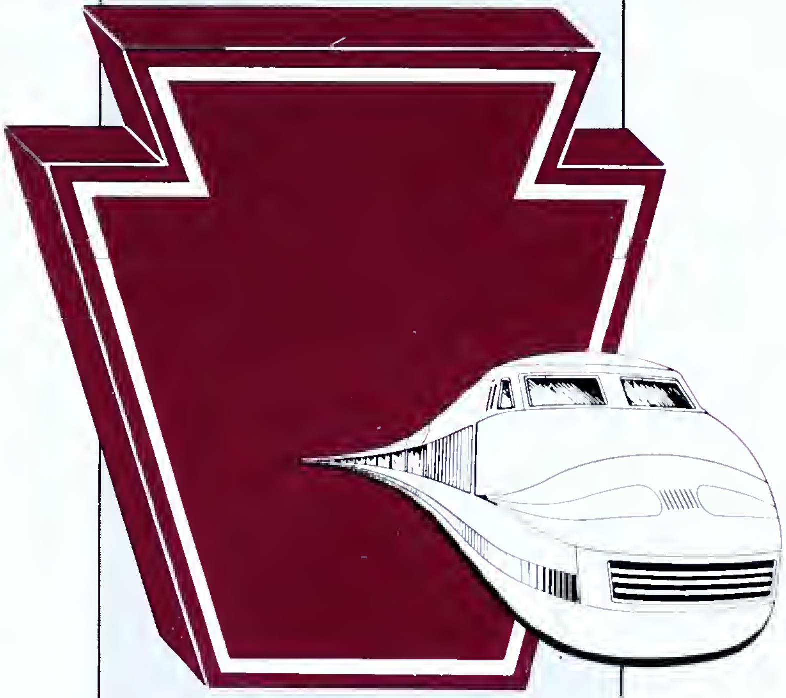
PENNSYLVANIA HIGH SPEED RAIL FEASIBILITY STUDY

EXECUTIVE SUMMARY

PHASE 1

PREPARED FOR:

PENNSYLVANIA
HIGH SPEED
INTERCITY
RAIL PASSENGER
COMMISSION



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FEBRUARY 1985

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SEP 12 1986

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The preparation of this report, dated February 1985, has been financed in part through a grant from the U.S. Department of Transportation, Federal Railroad Administration, to the Pennsylvania High Speed Intercity Rail Passenger Commission.

This executive summary is based on methodology, data, and assumptions contained in the study working papers and reports. Included in the assumptions are projections, made as of November 1984, concerning future events and economic conditions that cannot be assured. Therefore, actual results achieved may vary from the projections.

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DOCUMENTS SECTION

INTRODUCTION

A high-speed rail passenger system across Pennsylvania could not only offer rapid, all-weather travel between Philadelphia and Pittsburgh but also create tens of thousands of jobs, pump billions of dollars into the state economy, and spark countless opportunities for real estate development.

Such a super-railroad—able to move millions of riders a year from city center to city center in safety, style, and speed—also could boost state tax revenue by hundreds of millions of dollars and position Pennsylvania to export high-speed rail technology to other states.

In addition, such a network probably could generate enough revenue to pay its operating and maintenance costs, and perhaps make a contribution to the capital construction cost.

These are among the preliminary findings of a program begun in 1983 for the Pennsylvania High Speed Intercity Rail Passenger Commission by an engineering joint venture of Parsons Brinckerhoff Quade & Douglas, Inc., and Gannett Fleming Transportation Engineers, Inc.

Under most of the options studied, comfortable trains would zip along on approximately hourly schedules. The trains would ride new passenger-only trackage separate from existing freight tracks (but in many locations adjacent and parallel to them) and free from grade crossings.

By the year 2000, the study estimates, a high-speed rail system could carry 4 million to 12 million riders a year. The figure could run even higher if rail connections materialize at either end of the state—to Atlantic City, N.J., and to a proposed multistate Midwest high-speed network that has been envisioned to link Pittsburgh with Cleveland, Detroit, and Chicago.

Building the railroad, an 8- to 12-year program, could help stabilize the state's economy at a time when the national shift to a service society has forced many smokestack industries to close their plant gates.

Clearly, Pennsylvania stands at a crossroads of economic opportunity with high-speed rail.

For travelers, this service could slice the nearly 7-hour, 352-mile passenger-train run from Philadelphia to Pittsburgh to as little as:

- 2¼ hours (express service) for new magnetic levitation trains on special guideways, or
- 3¼ hours for advanced high-speed trains on steel wheels following a mostly new alignment, or
- 4 hours for a substantially improved steel-wheel system primarily following the existing right-of-way.

Such a system would give Pennsylvania a quality and frequency of service unknown in America but widely available in Japan and Europe, where clean trains safely and routinely whisk between major cities at speeds of between 125 mph and 168 mph. It also would help meet a growing demand for intercity transportation, which is expected to nearly double by the year 2000, according to a federal study.

The main line envisioned by the Commission's study would connect with Amtrak's New York-Washington Northeast Corridor at 30th Street Station in Philadelphia. In Pittsburgh, the line could terminate either at Pennsylvania Station, as Amtrak trains now do, or at Station Square, the P&LE Terminal complex being redeveloped as a retail-hotel-restaurant center. Some of the route alignments studied closely follow the former Pennsylvania Railroad main line (today owned by Amtrak east of Harrisburg and by Conrail west of Harrisburg) for much of the distance, while others deviate widely from it. In all cases studied, however, trains would serve Paoli, Lancaster, Harrisburg, Altoona, Johnstown, and Greensburg. One route realignment proposal would add State College, home of Pennsylvania State University and a growing center for technology and research.

Highlights of other findings, which are covered elsewhere in this executive summary and in detail in the technical study itself, are listed below. Known as Phase 1, this part of the study laid a broad framework for more specific and intensive examination in Phase 2. Phase 2 will include a detailed market survey and a right-of-way inventory. Phase 3 will focus on economic development that high-speed rail (HSR) could stimulate and on a financing package.

Among other findings, Phase 1 determined that:

- Pennsylvania residents and firms can capture approximately 70 percent of the construction costs ($1.8 billion to build a 4-hour steel-rail system, up to $10 billion to build a 2½-hour [trains making all stops] magnetic levitation [maglev] system).
- Pennsylvania residents and firms can capture an even greater share—approximately 80 percent—of operating expenditures, year after year.
- A "multiplier effect" of successive rounds of spending might triple the impact of initial expenditures.
- The dollar value of time savings alone could exceed the capital costs of an HSR system.
- State tax revenues would increase.
- New jobs directly created in Pennsylvania by HSR can boost the Commonwealth's employment growth rate by 20 to 68 percent during the construction period and by 23 to 35 percent when service begins, depending on which of the high-speed rail systems is chosen.
- Existing commuter systems, such as the Southeastern Pennsylvania Transportation Authority (SEPTA) and Port Authority Transit of Allegheny County (PAT) might gain riders by serving as feeder service to HSR.
- Pennsylvania firms could leap to the forefront of a new HSR industry in the United States, benefiting from the development of a trained labor force, a strengthened base for an HSR supply industry, and investments in the new technology drawn to Pennsylvania by an HSR system.
- The competitive position of Pennsylvania industries relative to those of other states could be enhanced by the better transportation HSR will provide. This definite transportation advantage and its intangible effect on the state's image could attract new businesses.

JNR Series 961 Bullet Train

SNCF TGV Train

British Rail HST Train

- Tourism could benefit. As tourists are drawn from farther afield by the improved accessibility, this market improvement might induce the creation of new tourist attractions and better amenities, drawing still more tourists in a synergistic effect. HSR service itself could be a tourist attraction, particularly in the more advanced forms.

PENNSYLVANIA AND THE WORLD'S HIGH SPEED RAIL SYSTEMS

State Perspective. Pennsylvania has always been in the vanguard in the development of transportation, including canals, railroads, and the world's first limited-access superhighway, the Pennsylvania Turnpike, which is a financial success as well as an efficient transportation facility. Some of America's earlier fast trains were in Pennsylvania—in 1956 the Aerotrain's low center of gravity allowed it to traverse the largely twisting and mountainous Pennsylvania Railroad main line at speeds of well over 85 mph, reducing the travel time between Philadelphia and Pittsburgh to 6 hours—an hour less than the currently scheduled time. But in Pennsylvania as elsewhere in the country, the years from the 1950s on have brought comparative neglect of the rail system as national transportation policy—and heavy federal funding—gravitated toward an emphasis on highways and airports. To remedy the neglect of rail, boost the state's economy, and regain a leading role in transportation, the Pennsylvania General Assembly created the High Speed Intercity Rail Passenger Commission by Act 144 of 1981 "to investigate, study and make recommendations concerning the need for and establishment and operation of a high speed intercity rail passenger system in the Commonwealth."

National Trends. The need for HSR passenger service is dictated by transportation growth trends. The final report of the National Transportation Policy Study Commission (1979) estimated that, even if the population were to stay constant in the 25-year period from 1975 to 2000, the number of intercity person-trips could be expected to rise by some 88 percent, from more than 13.5 billion annually to nearly 25.5 billion. According to the study, this results from the following trends:

- Expansion of service industries and white-collar occupations will cause business travel to increase faster than general economic growth.
- Increased affluence and leisure time will stimulate pleasure travel.
- Changing age distributions mean that there will be more persons in high-travel-potential age groups.
- The trend toward fewer dependents will allow more time and disposable income for travel.
- The rising relative affluence of other countries will increase tourism to the United States.

The federal study took special note of the absence of an efficient travel mode for short-distance intercity markets—a niche HSR might fill:

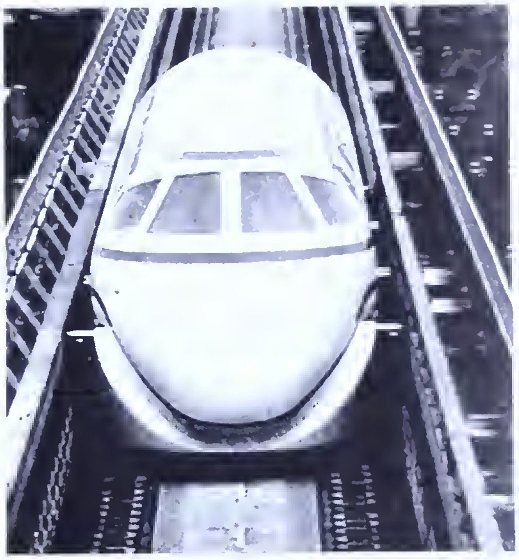
> Present intercity service offers limited speed and cost options. In short-range markets, there are no substantial high-speed options—air being relatively slow due to excessive access times, and the auto and bus being fixed at a maximum upper speed limit of 55 miles per hour. This market is often indicated as having potential for high-speed rail service; however, substantial capital investment is required. Where auto, bus and air speeds are often impaired by road and airway congestion, rail services may gain market share when rail speeds and service levels begin to compare favorably with the other modes.

The World View. Two basic systems were selected from world technologies as possible models for Pennsylvania:

- Steel-wheel-on-steel-rail. These systems are currently running at speeds of 125 mph or more in France, Great Britain and Japan—hundreds of route-miles in each country. They are fast, comfortable, and—particularly those propelled by electric power—produce little wayside air pollution. For electric trains, combustion takes place in the power generating plant, where it can be controlled, and fuel at the plant can be coal or hydropower instead of scarce oil. The initial Japanese high-speed line, known as the Shinkansen, has been running "Bullet Trains" since

VIA Rail LRC Train

Transrapid 06 Maglev Test Train



JNR MLU-001 Maglev Test Car

1964—at a profit year after year. Tested at a maximum speed of 198 mph and operating at about 130 mph, it has sped along for more than 20 years without a single fatality or serious injury to passengers, making it the safest transportation system in history. The new French TGV (très grande vitesse or "very high speed") trains run even faster—168 mph normal top speed; tested to as high as 236 mph—again, at a profit for the initial line. Since 1975, British Rail has operated "Inter-City 125" service with HST (High-Speed Train) diesel-powered equipment at 125 mph. In addition, British Rail is running an electric-powered train called APT (Advanced Passenger Train) with coaches that tilt, enabling them to round conventional curves faster than otherwise would be comfortable for passengers. Canada also has a tilt-body design, the LRC (Light, Rapid, Comfortable), in service and undergoing continuing development. Using AEM-7 electric locomotives with Swedish-licensed technology and Amfleet coaches, Amtrak's Northeast Corridor intercity service runs at a top speed of 120 mph on certain stretches.

- Maglev. In a magnetic levitation, or maglev, system, magnets on the train interact with conductors embedded in a special guideway, propelling the train forward and, as it gathers speed, lifting it up. The train floats from a fraction of an inch to a few inches above the guideway surface itself, avoiding contact noise, vibration, and friction. Experimental maglevs are now running in Japan and Germany at speeds as high as 250 mph, based on different approaches. They are termed "repulsion" and "attraction" maglevs respectively, after the differing ways in which each country uses magnets to provide levitation. An early Japanese maglev attained a world speed record of 321 mph. One maglev has entered low-speed regular service at the Birmingham Airport in England. For Pennsylvania, 250 mph seems a reasonable top practical speed—avoiding the worst aerodynamic drag and noise.

The Commission and eventually a broader group of Pennsylvania leaders will face one fundamental distinction between these two classes of HSR systems: maglev operates on a different principle from rail, requires its own guideways, and cannot be simply added on to an existing rail system. Steel-wheel-on-steel-rail technology, on the other hand, can be developed by stages, with advanced vehicles running at less than top speeds over ordinary tracks for a time, or a diesel system built first and electrified later.

ALTERNATIVES FOR PENNSYLVANIA

Achieving Higher Speeds. Travel times can be cut by using combinations of engineering techniques. Several alternative systems are described here, each using an integrated combination of track, alignment, operations, and equipment improvements. Among track, alignment, and operations improvements considered in the study were:

- Upgrading track to higher Federal Railroad Administration (FRA) classification—may be a requirement for higher speed.
- Raising superelevation (banking curves more steeply)—an inexpensive way of obtaining higher speed curves if track can be "dedicated" to passenger service.
- "Designation" of track for passenger service—may avoid the expense of constructing additional trackage specifically designed and dedicated for passenger service.
- Curve straightening—may avoid the cost and impact of route realignment, with nearly the same improvement in speed capability.
- Route realignment—may be desirable in areas where existing route is circuitous or where sharp curves exist.
- New alignment—may be the only way to obtain desired shorter trip times.

Among equipment improvements considered in the study were various combinations of the following:

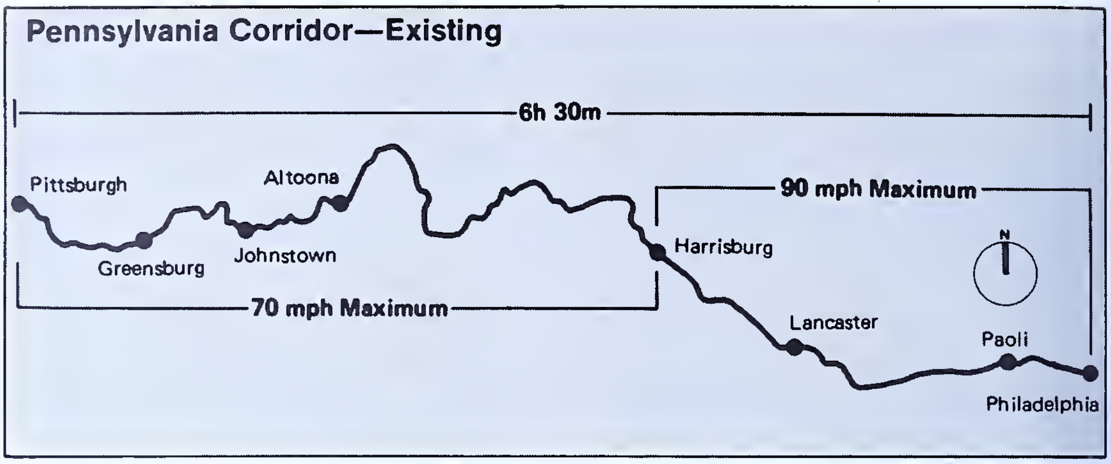
- Increased power density (horsepower per ton)—may provide improved performance at a reasonable cost.
- Running with increased cant deficiency (tilt-body vehicles)—may increase passenger comfort and raise speed on curves, thus significantly improving performance at a reasonable cost.
- Electrification—though costly be-

cause of the need for an overhead catenary, saves train weight and may be the best way to provide the desired performance.

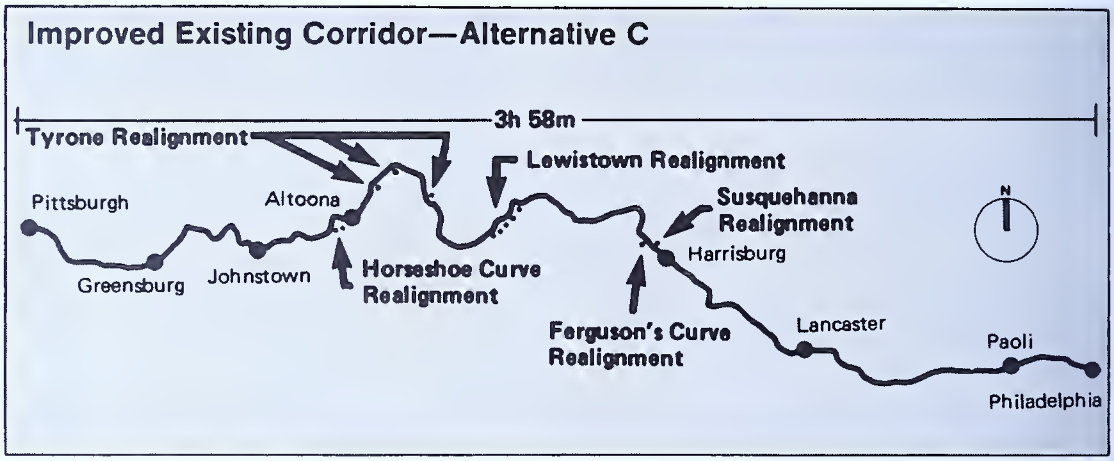
- Advanced technology (maglev)—though costly and not yet proven in commercial operations, it is the only way to provide ground transportation times as low as 2¼ hours (express) between Philadelphia and Pittsburgh.

Existing Service. Today, Amtrak cross-state passenger trains (the Broadway Limited and the Pennsylvanian) use Electro-Motive F40PH-type diesel locomotives to draw Amfleet and Heritage Fleet cars. The trip is slow, averaging 47 to 50 mph, mainly because of track and route bottlenecks and because of the mixture of freight and passenger trains on one of the highest tonnage railroads in the country. The 352-mile route has 40 grade crossings, 593 bridges, two tunnels, and 392 curves, or 1.1 per mile, a substantial proportion. With top speeds of 70 mph on the Conrail line west of Harrisburg and 90 mph on the Amtrak line east of Harrisburg, total trip time is a calculated 6½ hours, though currently scheduled with leeway at 6 hours 56 minutes. Amtrak service on the electrified Philadelphia-Harrisburg line is more frequent—nine trains a day each weekday—and runs at a slightly higher average speed—about 65 mph. These trains use Budd-built Metroliner coaches originally used in Northeast Corridor service.

The study focuses on three progressively faster—and costlier—systems, each of which uses a specific vehicle type and route alignment. For purposes of the study, these are Alternatives "C," "D," and "E." (Alternative "A" was existing or "baseline" service, used as a point of comparison only; and Alternative "B" embraced only minor improvements to existing service—it was dropped from further consideration because it fell too far short of the Commission's stated performance goals.)



Pennsylvania Corridor—Existing



Improved Existing Corridor—Alternative C

Cities to be Served. In all alternatives, seven population centers would be served, as required in the Commission's original Request for Proposal: Lancaster, Harrisburg, Altoona, Johnstown, and Greensburg, in addition to the terminal cities of Pittsburgh and Philadelphia. Service at Paoli was also examined to draw on the large suburban ridership base of the metropolitan Philadelphia area, including the new high-tech corridor that is developing along Route 202 near Paoli. Another growing high-tech area, Centre County, could be served by a routing through State College (studied under Alternative D, but also possible under C or E).

The details of providing commuter service and intermediate stops can be studied later, but it should be possible to operate these services in coordination with through trains.

Alternative C—Improved Existing. Alternative C is a big step up from the existing service, and could well serve as a transition to even higher-speed service later. It represents the best service that could be provided on essentially the existing right-of-way (or one parallel to it) with dedicated passenger tracks, limited curve improvements at many points, and route realignments at five current bottlenecks. Listed east to west, these realignments are:

- Susquehanna River reroute: runs north from Rockville, roughly following Conrail's Harrisburg-Buffalo main line and crossing river to Duncannon (saving 9.0 minutes).
- Ferguson's Curve east of Newport: straightens wide curve along the Juniata River (2.3 minutes).
- Lewistown to west of McVeytown: follows base of Blue Mountain on straight alignment (12.3 minutes).
- Tyrone: series of curve straightenings between Petersburg and Tyrone (15.3 minutes).
- Horseshoe Curve: bypasses the historic engineering landmark on a high viaduct (6.3 minutes).

High-speed locomotives and cars would be used, perhaps of tilt-body design; grade crossings and other obstacles eliminated where possible; and speed, comfort, and reliability much improved. Diesel or electric locomotives could be used (the electified option was termed Alternative C—Electric): diesel offers freedom from the capital expense of electrification, but electric trains operating from wayside power offer quicker acceleration or higher top speed. Diesels might be either the Canadian LRC (a tilt-body train built to North

VIA Rail LRC Train (Canada)

British Rail HST Train

Amtrak AEM-7/Amfleet Train (United States)

American standards and used in Canada since 1982, desirable if substantial route curvature is present) or the lightweight but nontilting British HST. Several electric trainsets are candidates in Alternative C—Electric: the American AEM-7 locomotive with Amfleet cars, as used in current Metroliner service on the Northeast Corridor; an electric version of Canada's LRC now under development; the West German ET 402, the Italian ETR 401 (tilt-body); or the British APT (tilt-body). Top speeds in this improved existing system would be 110 to 120 mph—nearly as high as true HSR service—and the trains could sustain high speeds throughout more of the trip than at present for substantially improved typical trip times (estimated at 3 hours 58 minutes; or 3 hours 50 minutes if electrified—both times assume trains stop at all stations considered in the study). Many of the improvements envisioned in Alternative C can be seen as steps toward even higher-speed service, allowing a smooth transition and the early inauguration of a service much superior to the present standard.

Alternative D—True High Speed Rail. Alternative D represents the best service possible with advanced steel-wheel-on-steel-rail rolling stock and motive power, using essentially new right-of-way. It uses a new alignment and advanced HSR technology modeled after the French TGV or Japanese Bullet Train, but realistically adapted to Pennsylvania topography to avoid excessive construction through tunnels or on structures. Three trainsets are candidates:

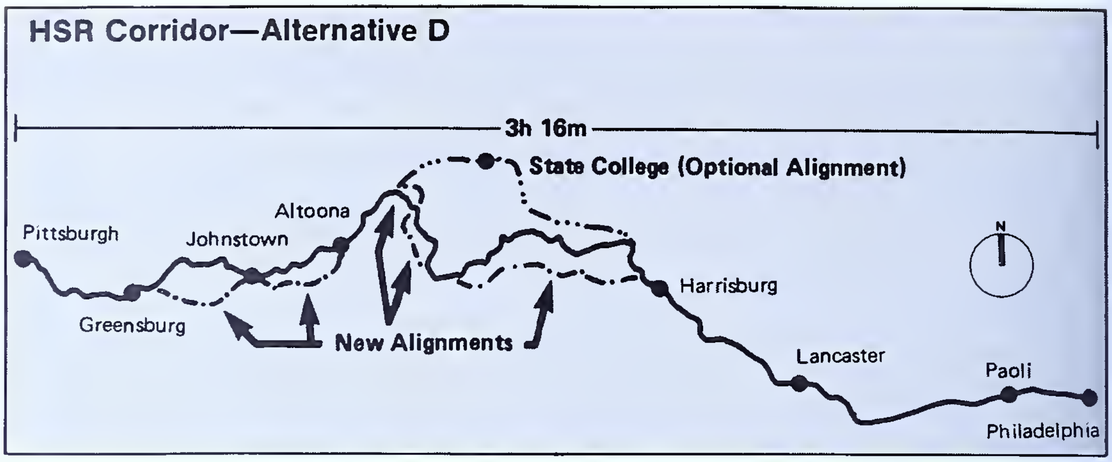
- French TGV (currently operating to as high as 168 mph; the export version intended for the United States would use synchronous alternating-current traction motors in place of the direct-current motors used in France).
- Japanese Series 961 Bullet Train (currently operating at 130 mph and somewhat more powerful than others in the Bullet Train series).
- Proposed German Intercity Experimental (IC-E) train (expected to begin prototype testing in December 1985).

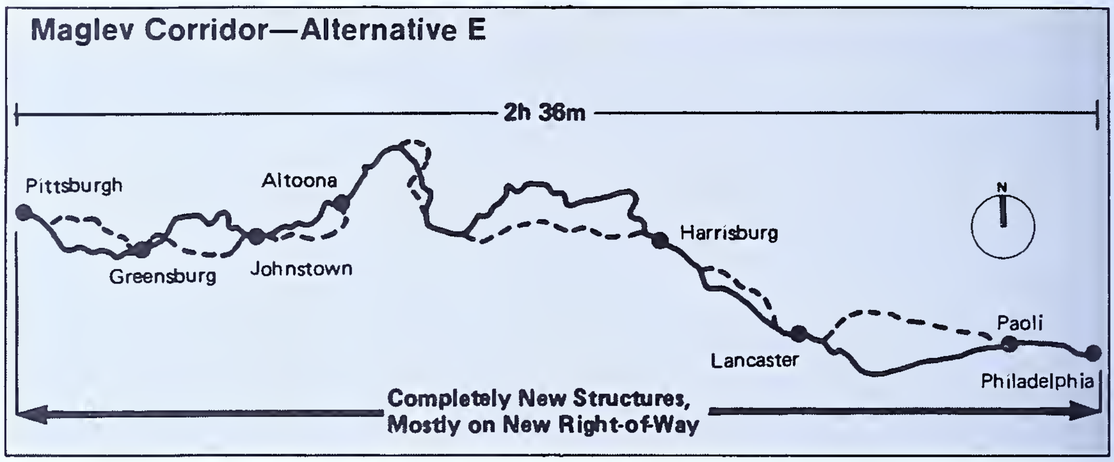
As originally conceived, Alternative D would not have followed the existing Amtrak/Conrail route as much as it does; an analysis of the marginal trip time savings, the high cost, and the large environmental impact of new alignments in urban areas, however, persuaded the study team to propose using the existing right-of-way between Philadelphia and Harrisburg, between Greensburg and Pittsburgh, and in the vicinity of passenger stations; elsewhere it would be new. Electrically powered trains would operate on new, passenger-dedicated trackage at a top speed of 160 mph (180 mph was also analyzed, but grade and curvature severely limit the marginal trip time savings). With six intermediate stops, the 314-mile route would take an estimated 3 hours 16 minutes.

Alternative D—State College. An alternative routing via State College was examined, the only realignment studied for market reasons rather than for trip-time improvement. Although studied as a variant of Alternative D, placing State College on an HSR corridor also could be done with Alternative C or E.

West of Harrisburg, the line would follow the Conrail main line as far as Millerstown, where it would diverge, tunneling through three mountains before emerging into the Nittany Valley. The route would pass south of State College and climb over Bald Eagle Mountain, joining the right-of-way of the former Conrail Bald Eagle Branch a few miles west of Port Matilda. From there, the alignment follows the branch until joining the main line at Tyrone.

This realignment would add about 5 miles and 10 to 12 minutes to the running time estimated for Alternative D. The cost of routing Alternative D through State College is estimated at $77 million above the base cost for Alternative D. If built as part of Alternative C, it would save about 7 minutes of running time. The cost of routing Alternative C through State College, while not estimated in Phase 1, would be substantial. For Alternative D, the additional market could boost ridership by as much as 650 to 1,690 passengers a day, or 237,250 to 616,850 riders annually.




Maglev Corridor—Alternative E
2h 36m
Pittsburgh
Altoona
N
Harrisburg
Greensburg
Johnstown
Paoli
Lancaster
Philadelphia
Completely New Structures, Mostly on New Right-of-Way

JNR Series 961 Bullet Train (Japan)

SNCF TGV Train (France)

Transrapid 06 Maglev Test Train (Germany)

JNR MLU-001 Maglev Test Car (Japan)

Alternative E—Magnetic Levitation. Alternative E represents the best service possible with magnetic levitation, using a totally new right-of-way. This new very-high-speed system could be modeled after either of two experimental vehicles:

- German attraction maglev, using a T-shaped guideway
- Japanese repulsion maglev, using superconducting coils and a U-shaped guideway.

A new system of guideway would be built within a portion of the existing right-of-way between Philadelphia and Malvern, and on a new right-of-way from there west to Pittsburgh. The guideway would principally be double, but near stations it would return to the existing right-of-way and become single. A full double guideway would be impractical in narrow rights-of-way through cities. Elevating the guideway when crossing sensitive areas such as farmland would permit continued use of the surrounding land. Tunneling and earthwork can be minimized because maglev can negotiate steeper grades than steel-wheel HSR systems (the study assumed use of 6 percent grades, though steeper grades are possible). Maglev acceleration and maximum speed are high enough that route length (313 miles) becomes a secondary issue, and straightness of primary concern. Speeds as high as 250 mph would be practical, providing an estimated trip time of 2 hours 36 minutes if all station stops are made.

Infrastructure Component Summary

Item	Alternative C	 C-Electric	 D	 E
Track	Upgraded existing 2 tracks (Philadelphia-Harrisburg) 1.5 new tracks (Harrisburg-Pittsburgh) (wood ties)		Entirely new double (concrete tie) track	New guideway
Maximum Track Superelevation/Guideway Bank Angle	6"		6"	12°
Maximum Grade	3 percent		3.5 percent	6 percent
Maximum Speed (mph)	110-120		160-180	250
Grade Crossings	Eliminated where feasible		100% eliminated	100% eliminated
Fencing	10% of ROW	10% of ROW & OH Bridge	100% at-grade ROW & OH Bridge	100% at-grade ROW & OH Bridge
Electrification	Not used	Upgraded: Philadelphia-Harrisburg New: Harrisburg-Pittsburgh	Upgraded: Philadelphia-Harrisburg New: Harrisburg-Pittsburgh	All new
Communications & Signals	Upgraded existing	Upgraded: Philadelphia-Harrisburg New: Harrisburg Pittsburgh	All new	All new
Stations	Rehabilitated existing and new (high-level platforms)		Rehabilitated existing and new (high-level platforms)	All new
Maintenance Facilities	All new		All new	All new

COST ESTIMATES

Cost estimates are shown in the table. For a system that would handle a base ridership demand (more conservative estimate), the target estimates range from $1.8 billion for Alternative C to $7.2 billion for D and $10.0 billion for E.

BENEFITS

Transportation Benefits. HSR brings shorter trip times—as low as 2½ hours end-to-end for Alternative E (maglev). Riders also benefit from the greater choice of arrival and departure times and the generally better service than that available today. The better the service and the more advanced the HSR system, the more riders attracted: Alternative C is estimated to draw an annual base demand of 4 million passengers, Alternative E nearly 6 million.

Time savings are fundamental. Over the years, the dollar value of these time savings could equal the

Capital Cost Estimate Summary

Base Demand, 1983 Dollars in Millions

Element	Alternative C	 C-Electric	 D	 D-State College	 E
Track/Guideway & Structures	$ 997.7	$ 1,051.1	$ 4,646.4	$ 4,671.1	$ 4,304.2
Stations	31.7	31.7	40.8	45.1	48.6
Electrification, Communications & Signaling	128.6	325.9	384.1	412.3	2,678.2
Maintenance Facilities	50.2	55.5	61.8	61.8	105.5
Subtotal 1	$ 1,208.3	$ 1,464.2	$ 5,133.1	$ 5,190.3	$ 7,136.5
Engineering & Construction Management @ 18%	217.5	263.6	924.0	934.3	1,284.6
Subtotal 2	$ 1,425.8	$ 1,727.8	$ 6,057.1	$ 6,124.6	$ 8,421.1
Contingency @ 15%	213.9	259.2	908.6	918.7	1,263.2
Subtotal 3	$ 1,639.7	$ 1,987.0	$ 6,965.7	$ 7,043.3	$ 9,684.3
Vehicles (Including Test @ 10% & Contingency)	205.2	216.8	203.3	203.3	339.8
Target Cost Estimate	$ 1,844.9	$ 2,203.8	$ 7,169.0	$ 7,246.6	$ 10,024.1
Additional Contingency @ 25% of Subtotal 2	356.4	432.0	1,514.3	1,531.2	2,105.3
Maximum Cost Estimate	$ 2,201.3	$ 2,635.8	$ 8,683.3	$ 8,777.8	$ 12,129.4

Operating and Maintenance Costs
Base Demand, 1983 Dollars in Millions

Item	C	C-Electric	D	E
Track/Structures				
Labor	$ 15.64	$ 15.64	$ 19.78	$ 21.07
Material	15.24	15.24	15.40	12.89
Electrical Maintenance				
Labor	--	5.86	6.60	32.77
Material	--	2.77	3.08	21.49
Vehicle Maintenance				
Labor	17.73	9.57	15.84	11.64
Material	8.82	4.68	8.77	8.61
Station Operation & Maintenance				
Labor	5.92	5.92	6.95	9.91
Material	1.00	1.00	1.20	1.50
Signals & Communications Maintenance				
Labor	7.84	7.84	6.60	(Incl. in Elect.)
Material	2.77	2.77	3.70	
Train Operations				
Vehicle Crew	9.81	8.19	9.55	8.69
Power	8.17	10.98	11.41	18.74
Central Operations & Administration				
Operations Schedule	1.55	1.55	1.55	1.55
Administration	3.89	3.68	4.44	5.44
Material & Services	6.09	5.93	5.91	7.91
Insurance	1.71	1.71	1.97	2.43
Security	1.44	1.44	1.44	1.44
TOTAL	$107.62	$104.77	$124.19	$166.19

Selected Train Parameters

Parameter	C		C-Electric		D		E
Equipment Type	HST	Lightweight LRC	AEM7/ Amfleet	Electric LRC	TGV	961	TR-06
Proposed Base Case Train Consist	1-8-1	1-6-1	1-6	1-6-1	1-11-1	8	6
Train Weight (Tons) Fully Loaded *	395	560	430	500	640	605	375
Horsepower	4,500	7,000	7,000	12,000	8,650	11,800	13,200
Hp/Ton	11.4	12.5	16.3	24.0	13.5	19.5	35.2
Seating Capacity +	396	480	480	480	524	520	600
Assumes Maximum E_u (in)	4.5	9	4.5	9	4.5	4.5	3

(Columns C, C-Electric, D and E are Alternatives.)

* Weights of all foreign equipment include structural modifications thought to be required to meet U.S. requirements (Based on IPEEP).

+ Seating capacity based on Amfleet seating density for all but the TR-06 (Maglev) vehicle.

system's capital costs—in as little as 4.8 years for the lowest-cost Alternative C or 12.4 years for Alternative D and maglev (Alternative E), which save more time for more people, but also cost more.

Less favorable assumptions for ridership demand and for the value of time require longer payback periods, from 36.4 years (C) to 85.7 years (E), but in all cases, the value of time savings is a benefit to riders that could compensate public support.

Economic Benefits. Beyond these transportation benefits, HSR would boost employment, personal income, the gross state product, and state tax revenue.

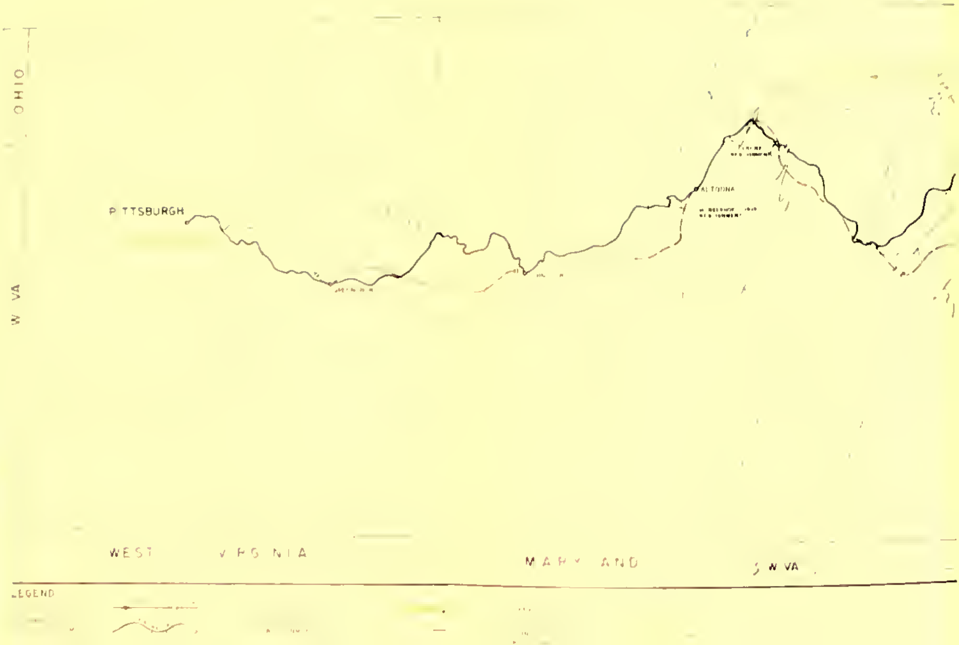
Unemployment is a key issue for Pennsylvania, as noted in the State Planning Board's 1980 *Choices for Pennsylvanians*:

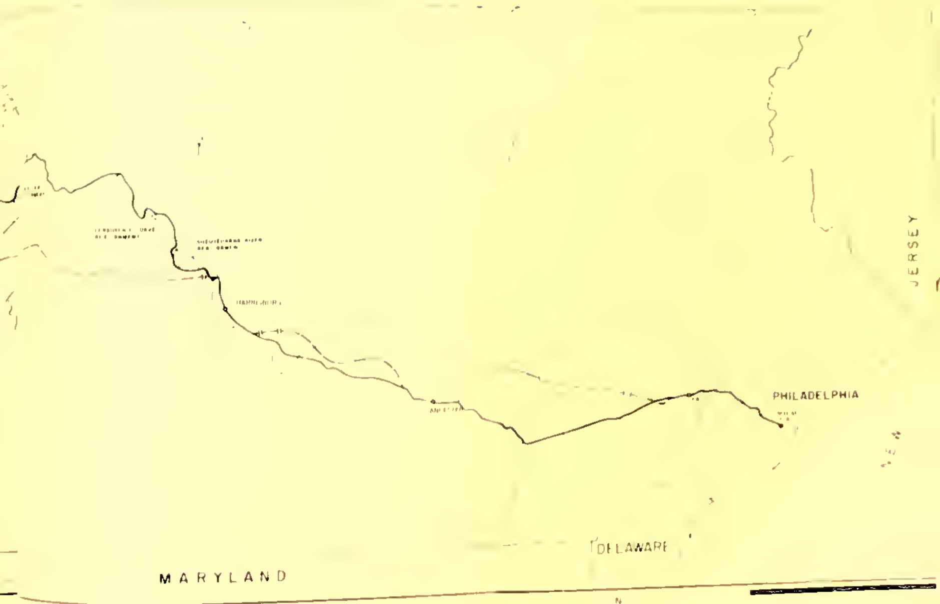
> In Pennsylvania, the lack of sufficient jobs is one of the most severe problems facing us today. During the last 10 years, the Commonwealth has lost 190,300 manufacturing jobs. . . . Hardest hit have been the cities and towns that once relied on factory and service workers for support of their economic base. Fewer people with fewer dollars has meant less business for the retail establishments and less municipal revenue for the communities of Pennsylvania.

These negative trends have continued since the 1980 report. HSR could provide:

- From 58,000 to 292,000 person-years of employment (for Alternatives C and E, respectively), or 7,000 to 24,000 jobs on average for each year of the construction period.
- New permanent employment once operation begins—8,300 jobs under Alternative C by the year 2000; 12,500 jobs under Alternative E.
- Increases in the employment growth rate of from 20 to 68 percent during construction years and from 23 to 35 percent when service begins.

Naturally, the more money spent on the system, the greater the returns, particularly during the construction period (8, 10, or 12 years for Alternatives C, D, and E, respec-


OHIO
W VA
PITTSBURGH
ALTOONA
WEST VIRGINIA
MARYLAND
W VA
LEGEND



NOTE: Where alternative alignments coincide with the existing route, only the existing route is indicated graphically

Pennsylvania Corridor Route Map

System Features

Item	Alternative C Improved Existing	 C-Electric Improved Existing (Electrified)	 D HSR	 E Maglev
Alignment	Base case: Existing route with 5 route realignments & 44 curve realignments		Existing Route: Philadelphia-Harrisburg and Greensburg-Pittsburgh New Route: Harrisburg-Greensburg	Existing Route: Philadelphia-Malvern New Route: Malvern-Pittsburgh
Track	Upgraded existing 2 tracks: Philadelphia-Harrisburg; 1.5 new tracks: Harrisburg-Pittsburgh (wood ties)		Entirely new double track (concrete tie)	New Guideway
Traffic Separation	Designated passenger tracks		Dedicated HSR	Dedicated
Maximum Effective Curve Elevation*	Up to 15" (6" E_a + 9" E_u)		Up to 10.5" (6" E_a + 4.5" E_u)	Up to 14.5" (12° bank angle + 3" E_u)
Maximum Grade	3 percent		3.5 percent	6 percent
Maximum Speed, mph	110 to 120		160 to 180	250
Grade Crossings	Eliminated where feasible		100% eliminated	100% eliminated
Fencing	10% of ROW	10% of ROW & overhead bridges	100% At-grade ROW & overhead bridges	100% At-grade ROW & overhead bridges
Electrification	Not used	Upgraded: Philadelphia-Harrisburg; New: Harrisburg-Pittsburgh	Upgraded: Philadelphia-Harrisburg; New: Harrisburg-Pittsburgh	All new
Signals & Communications	Upgraded existing	Upgraded: Philadelphia-Harrisburg; New: Harrisburg-Pittsburgh	All new	All new
Stations	Rehabilitated existing and new (high-level platforms)		Rehabilitated existing and new (high-level platforms)	All new
Maintenance Facilities	All new	All new	All new	All new
Equipment Type	Diesel trainset (tilt-body or conventional)	Electric trainset (tilt-body or conventional)	High-speed electric train	TR-06 or MLU-001 type train

* Maximum Effective Curve Elevation is defined as the sum of track superelevation (actual elevation, E_a) and unbalanced elevation (E_u).

Potential Payback from Time Savings

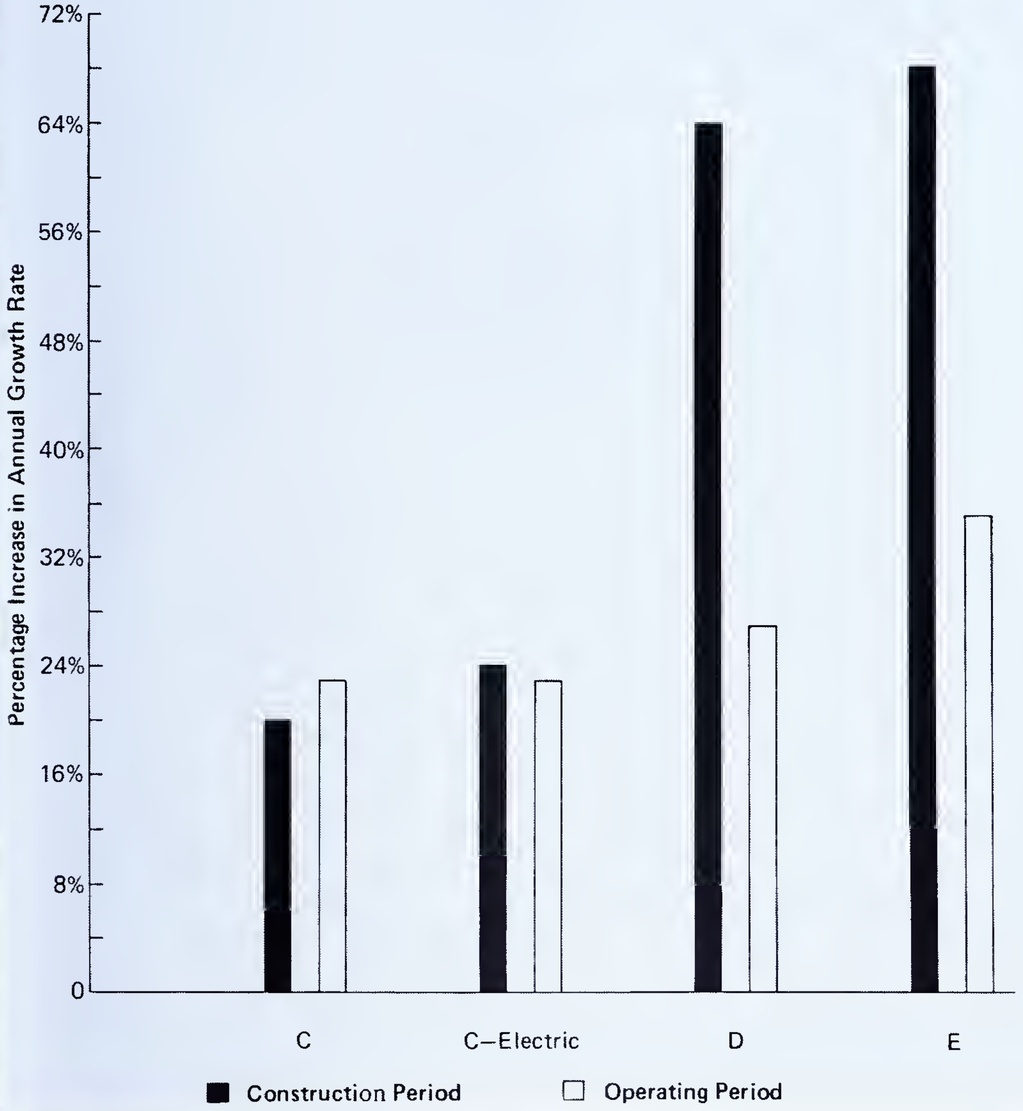
ALTERNATIVE	Demand	PAYBACK PERIOD, YEARS Case A	 Case B
C	Base	11.6	36.4
D	Base	27.3	85.7
E	Base	25.6	80.5
C	High	4.8	15.1
D	High	12.4	39.0
E	High	12.4	38.9

Typical Trip Times

	Existing TIME (MIN)	ALTERNATIVE C TIME (MIN)	 C-Electric TIME (MIN)	 D TIME (MIN)	 E TIME (MIN)
Philadelphia					
	23	19	18	19	16
Paoli					
	40	31	30	30	19
Lancaster					
	32	23	23	24	16
Harrisburg					
	145	79	76	55	53
Altoona					
	58	29	27	21	17
Johnstown					
	52	32	31	21	16
Greensburg					
	40	25	25	26	19
Pittsburgh					
Time, Total Route (hr:min)	390 (6:30)	238 (3:58)	230 (3:50)	196 (3:16)	156 (2:36)
Route Length, miles	352.0	340.1	340.1	314.3	312.9
Average Speed, mph	54	86	89	95	120

NOTE: Times include 90 sec dwell at all intermediate station stops.

Impact of HSR on Employment Growth Rate
Base Demand



Annual Ridership Summary
Year 2000 (thousands)

	Base Demand	High Demand
Alternative C		
Estimated Riders	4,183	10,256
Additional (Atlantic City)	32	77
Additional (Mid-State Resort)	110	430
Total	4,325	10,763
Alternative D		
Estimated Riders	5,146	11,676
Additional (Atlantic City)	43	74
Additional (Mid-State Resort)	110	430
Total	5,299	12,180
Alternative E		
Estimated Riders	5,866	12,658
Additional (Atlantic City)	51	87
Additional (Mid-State Resort)	130	500
Total	6,047	13,245

tively). Most of the money spent would stay in Pennsylvania—70 percent during construction and a continuing 80 percent after operation begins.

All alternatives provide the state government with additional financial resources that could assist in financing HSR, stemming solely from the existing tax structure:

- $12 million to $41 million per year during construction
- $13 million to $19 million per year during service, base ridership demand—or $18 million to $26 million, high ridership demand.

These additional tax revenues represent 1 percent or less of total current state government revenues, but boost the projected annual growth rate by as much as 31 percent. The additions could finance part of the HSR system's construction or operation, should the Commonwealth decide to make a financial commitment to the system. Costs to state government may decline modestly by the reduction in expenditures for new construction and for maintenance in other modes of transportation, and by the reduction in unemployment and associated public costs.

Urban economic development could be enhanced and downtown areas revitalized. New employment and greater personal income could be felt all along the route. How each city handles the fostering of development can make for differences among the cities. So can sheer size. The large urban areas have more heavy construction and railroad supply industries than the smaller ones and can capture larger percentages of Pennsylvania's share of construction costs: the Philadelphia Standard Metropolitan Statistical Area can capture 22 percent, Pittsburgh (including Greensburg) 28 percent. During both construction and operation, the larger general economies can also absorb more of the multiplier effect as new income is spent in the community. Proportionally, however, the smaller urban areas—Altoona, Harrisburg, Johnstown, and Lancaster—can look for equal or greater benefits relative to their smaller overall economies. Each city's success will depend on its own development policies and basic economic vitality, but HSR can become a strategic spur to growth.

Summing up, economic impacts to Pennsylvania of an HSR corridor could include:

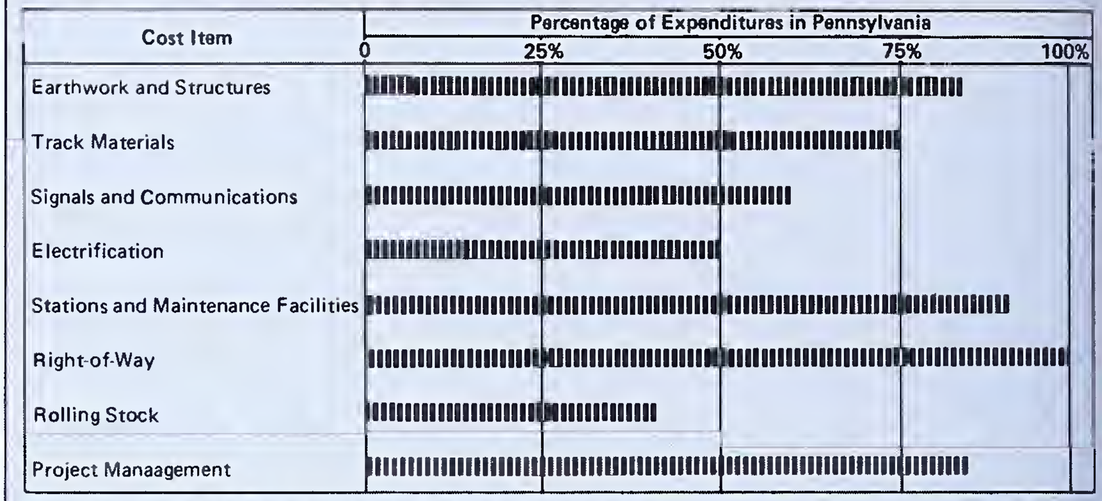
- $145 million to $415 million of new, direct expenditures annually during construction
- $115 million to $175 million annually during operation
- Total economic impacts over the 8- to 12-year construction period, including the multiplier effects of successive rounds of spending (approximately three times the size of the direct effects):
  - Between $3.9 billion and $22.7 billion in total expenditures for goods and services
  - Between $1.2 billion and $6.1 billion in gross state product
  - Between $1.0 billion and $5.2 billion in total personal income
  - Between 58,000 and 292,000 person-years of employment.

Relative Benefits of Alternatives. All the alternatives offer benefits, and in general, the greater the costs, the greater the benefits. Economic benefits correspond closely to costs, but transportation benefits begin to give less return per dollar at the highest costs. This behavior is typical of transportation projects: each additional minute of time savings costs more to achieve than the previous minute.

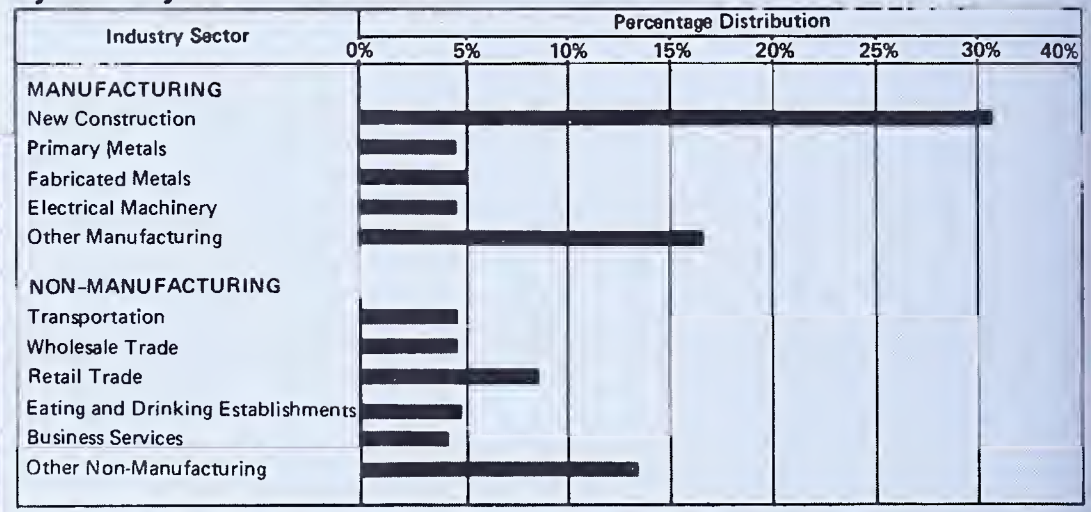
For producing transportation benefits, Alternatives D and E generate more total benefits than Alternative C, but at more than proportionately greater cost. For economic benefits, however, all are approximately equally efficient in generating benefits from costs.

Return on Investment. HSR could pay for its own operation. Sources of revenue include both fares and "other revenues"—associated business enterprises such as package service; baggage and mail fees; charter services to special events; auxiliary revenue from station concessions and advertising; and the rental of space in stations. From these are subtracted the costs of travel agent commissions, food-service losses on the trains, and advertising. Calculated this way, revenues for the first year of opera-

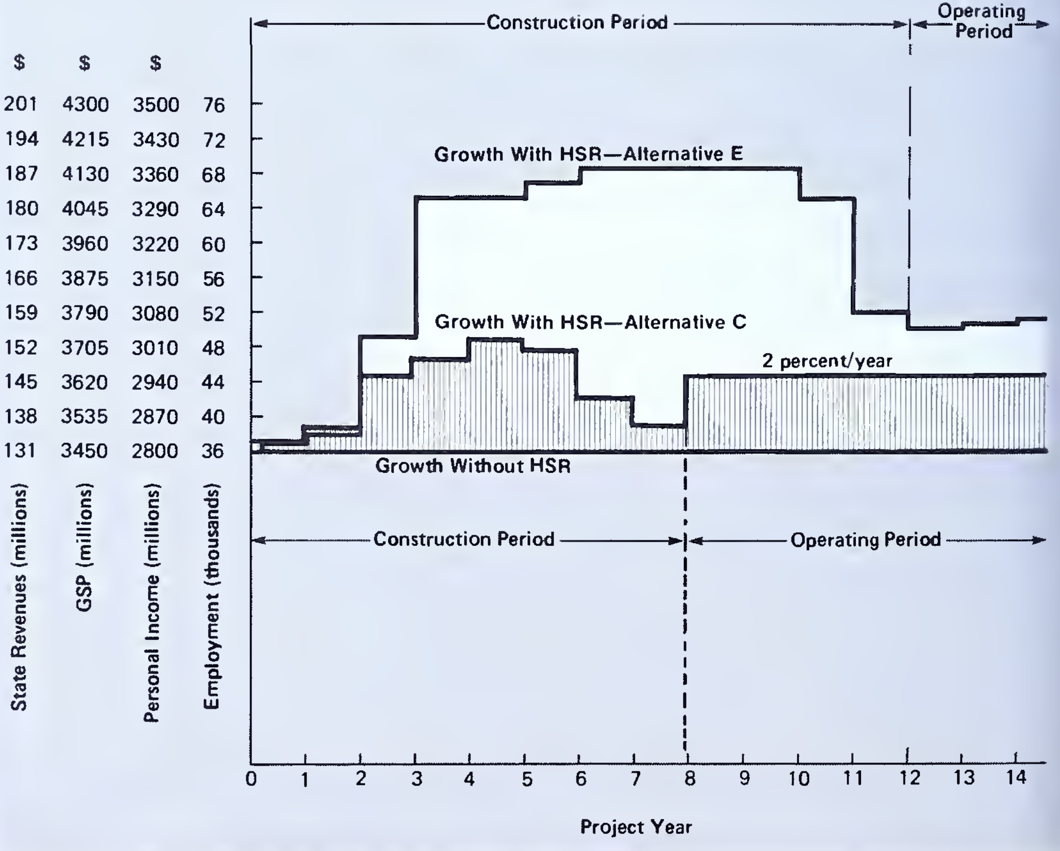
Pennsylvania's Estimated Share of Construction Expenditures



Distribution of Construction Period Impacts by Industry Sector—Alternative C



Impact of HSR on Economic Growth
Base Demand



Statewide Construction Period Impacts

Economic Indicator	Alternative			
	C	C-Electric	D	E
Capital Cost, millions	$ 1,845	$ 2,204	$ 7,169	$10,024
Number of Construction Years	8	8	10	12
Peak Year Expenditures	23%	23%	17%	11%
Pennsylvania Capture Rate	71%	70%	72%	66%
Employment Impact				
Direct, person-years	18,000	22,000	75,000	97,000
Total, person-years	58,000	67,000	232,000	292,000
Percent Increase in Pennsylvania Growth Rate	20%	24%	64%	68%
Personal Income				
Direct, millions	$ 400	$ 500	$ 1,500	$ 2,000
Total, millions	$ 1,000	$ 1,200	$ 4,100	$ 5,200
Percent Increase in Pennsylvania Growth Rate	4%	5%	14%	15%
Gross State Product, millions	$ 1,200	$ 1,400	$ 4,900	$ 6,100
Percent Increase in Pennsylvania Growth Rate	4%	5%	14%	15%
State Tax Revenues, millions	$ 95	$ 110	$ 385	$ 490
Percent Increase in Pennsylvania Growth Rate	9%	10%	30%	31%

Statewide Operating Period Impacts
Base Demand, Year 2000

Economic Indicator	Alternative			
	C	C-Electric	D	E
Annual O&M Cost, millions	$ 108	$ 105	$ 124	$ 166
Annual Ridership, millions	4.2	4.2	5.1	5.9
Employment Impact				
Direct, permanent jobs	4,500	4,400	5,300	6,800
Total, permanent jobs	8,300	8,100	9,600	12,500
Percent Increase in Pennsylvania Growth Rate	23%	23%	27	35%
Personal Income				
Direct, millions	$ 85	$ 85	$ 100	$ 125
Total, millions	$ 140	$ 140	$ 160	$ 205
Percent Increase in Pennsylvania Growth Rate	5%	5%	5%	7%
Gross State Product, millions	$ 165	$ 160	$ 190	$ 245
Percent Increase in Pennsylvania Growth Rate	5%	5%	5%	7%
State Tax Revenues, millions	$ 13	$ 13	$ 15	$ 19
Percent Increase in Pennsylvania Growth Rate	10%	10%	11%	15%

tion are expected to fall within the following ranges:

- Alternative C—$113.92 million to $289.73 million
- Alternative D—$141.77 million to $322.16 million (or from $153.68 million to $347.18 million if State College is added)
- Alternative E—$181.92 million to $389.39 million

A creative and flexible combination of public and private support may be workable for HSR. Each stage in the project has peculiar features affecting financing and taxes: the project might evolve in stages from public to public-private ownership and control, drawing on the special tax and financing advantages of each. Private investors will require a direct return on investment commensurate with the perceived risk in developing the system. At this stage in the study it appears that all the alternatives would return enough revenue to cover operating costs, with Alternative C providing the highest internal rate of return on investment. If capital costs must also be covered from revenues alone, private investors might need added incentives, particularly for the more expensive and higher-risk alternatives. Such alternatives, with their greater total public benefits but only somewhat greater cash revenues, are more suitable to a public financing viewpoint. When such benefits as employment and supplementary economic development are considered, a strong justification for public financial support of an HSR project could be made.

No new transportation system of this magnitude can be developed entirely risk-free. Some uncertainties must be associated with any piece of new construction on new right-of-way—which is extensive in Alternatives D and E. No system was considered in this study, however, that had not proven its technological feasibility. Alternative C uses essentially time-tested technology, except for the carbody tilt system. Alternative D also has a significant service record, but it has a greater implementation risk than C because it requires more new construction and greater care in building and maintaining track to close tolerances. Maglev has been proved as a functioning principle, but not in high-speed revenue service.

Particularly for maglev, private investors will require a higher rate of return than for a risk-free investment. At present, it appears that only Alternative C surpasses the risk-free rate of 9 percent, and then only from ridership above the base-demand conditions. It therefore seems likely that public policy, rather than investment profitability, will decide the level of support for HSR. As the study continues, public policymakers must eventually decide whether benefits themselves—time savings, greater economic impact—should be maximized, as in Alternatives D and E, or the efficiency of achieving those benefits (Alternative C).

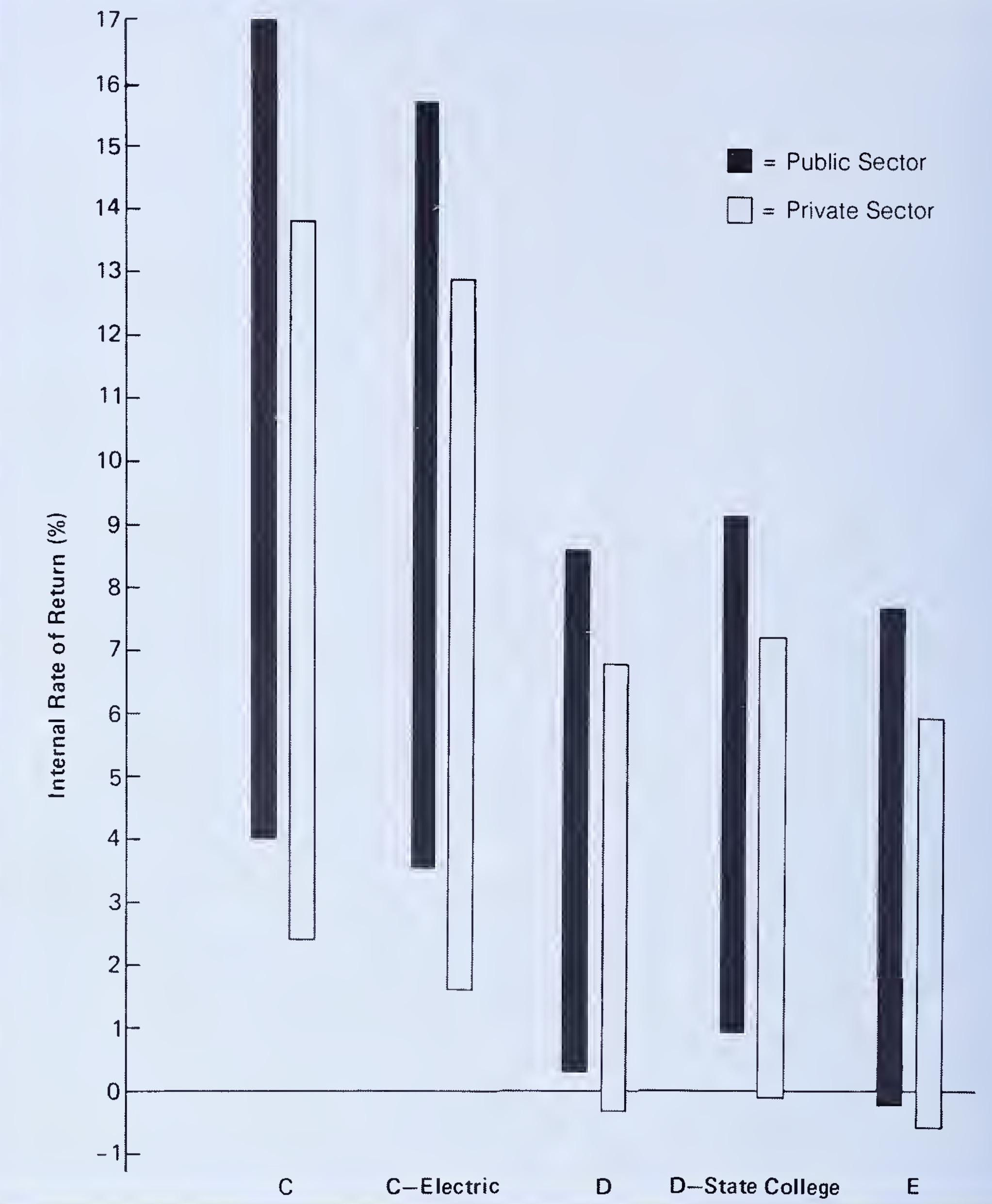
The alternatives so far considered are only first approaches. Later stages of the study will modify them, perhaps gaining important financial advantages. It is likely that vendors of equipment would offer support through loan guarantees as a way of penetrating a new market and gaining a showcase for their equipment. Adding State College to the route could raise ridership; innovative financing can also be explored, including such approaches as Florida's plan for financing transportation by allowing private investors to share in the profits of land development spurred by the new travel corridor.

ENVIRONMENTAL IMPACT

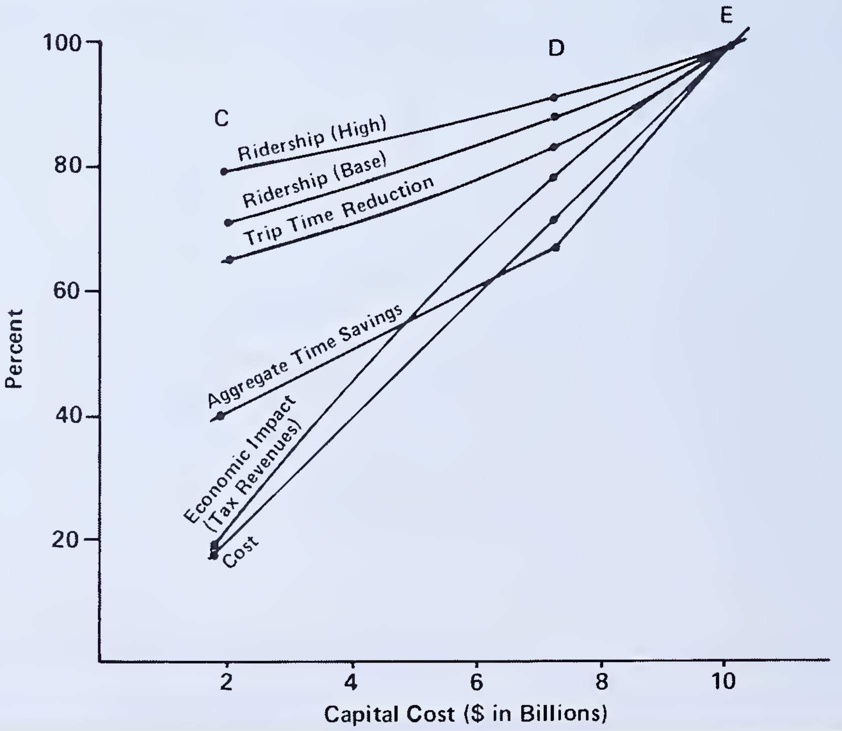
HSR will be a good neighbor. Rail in general requires only a thin strip of land to provide efficient transportation on a large scale. In virtually all categories—land required, energy consumption, noise, vibration, air pollution, and aesthetic intrusion—railroads are recognized as potentially less damaging to the environment than freeways or airports.

Land Use. For the Pennsylvania HSR line, major wetlands and state parks seem, in this preliminary overview, little affected by the planned route, except that Alternative E crosses one corner of Marsh Creek State Park in Chester County. Much of any new right-of-way will necessarily cross tracts of farm and forest that will need sensitive treatment,

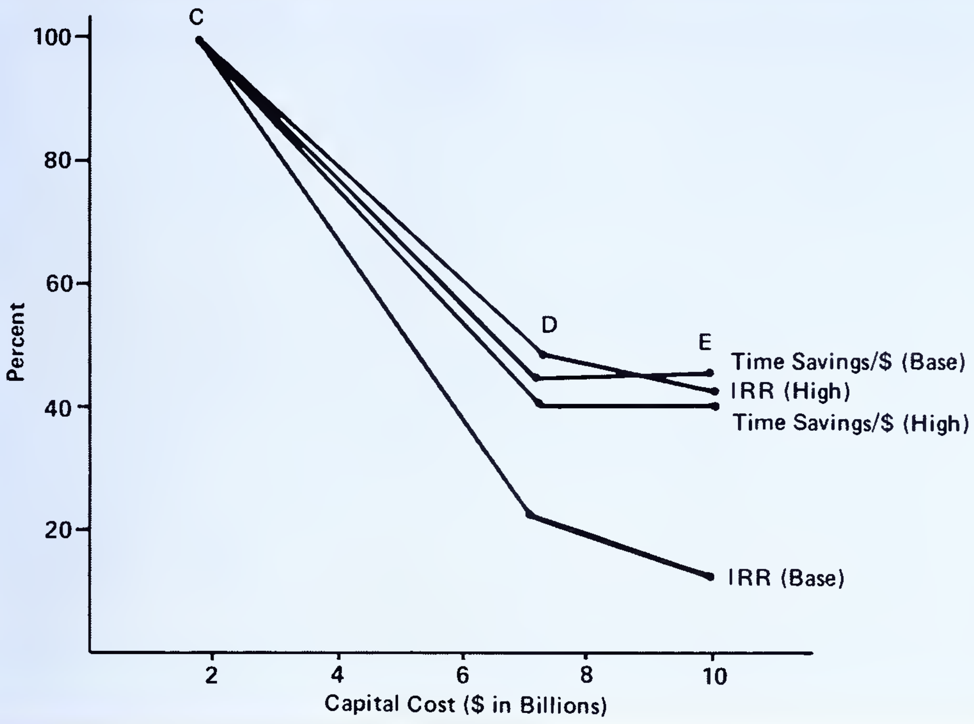
Range of Internal Rates of Return



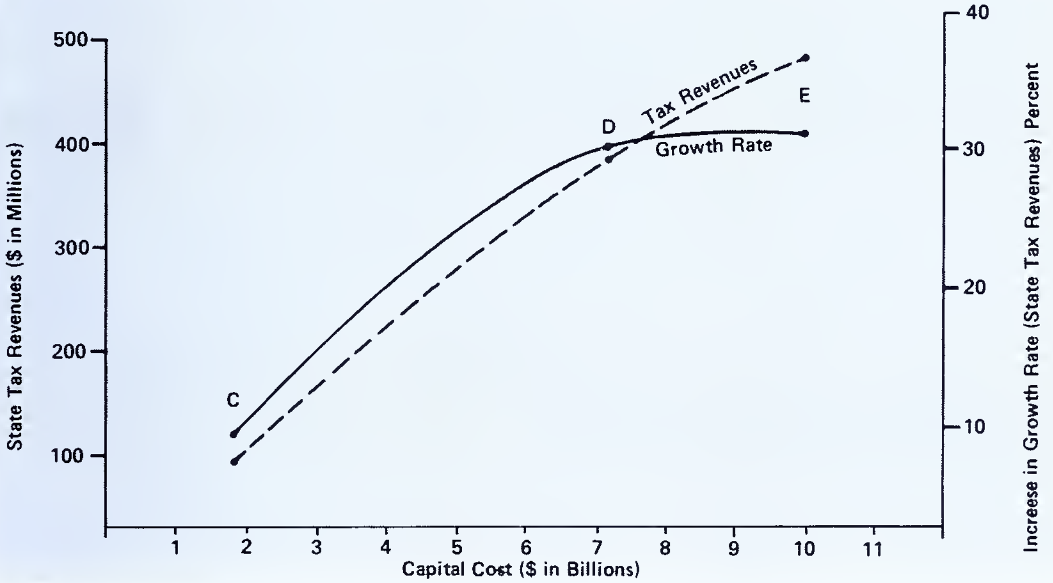
Normalized Performance Indicators



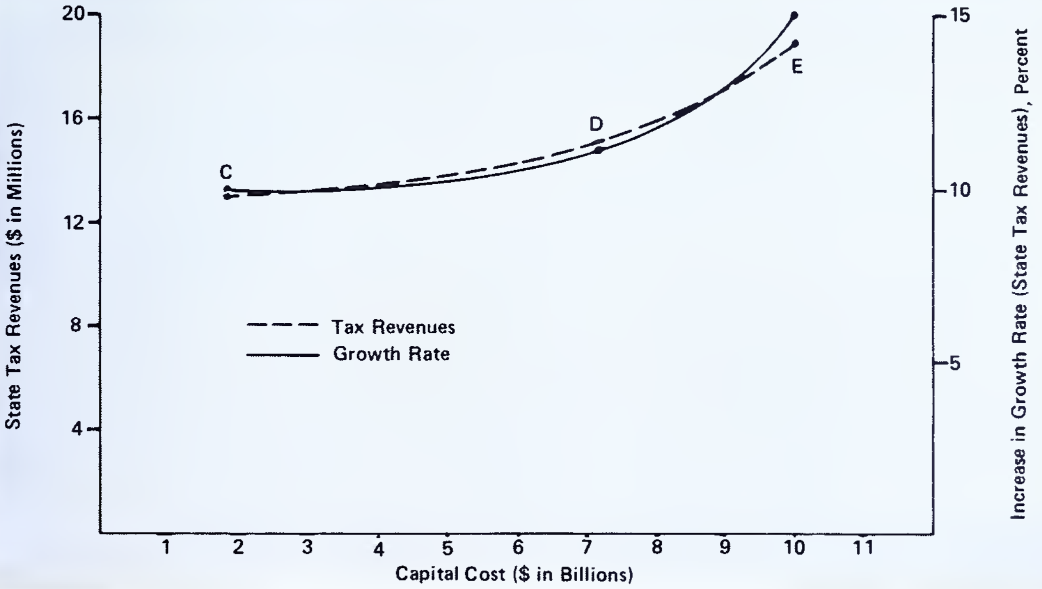
Normalized Cost-Based Performance Indicators



State Tax Revenue and Growth Rate Increase—Construction Period



State Tax Revenue and Growth Rate Increase—Operating Period



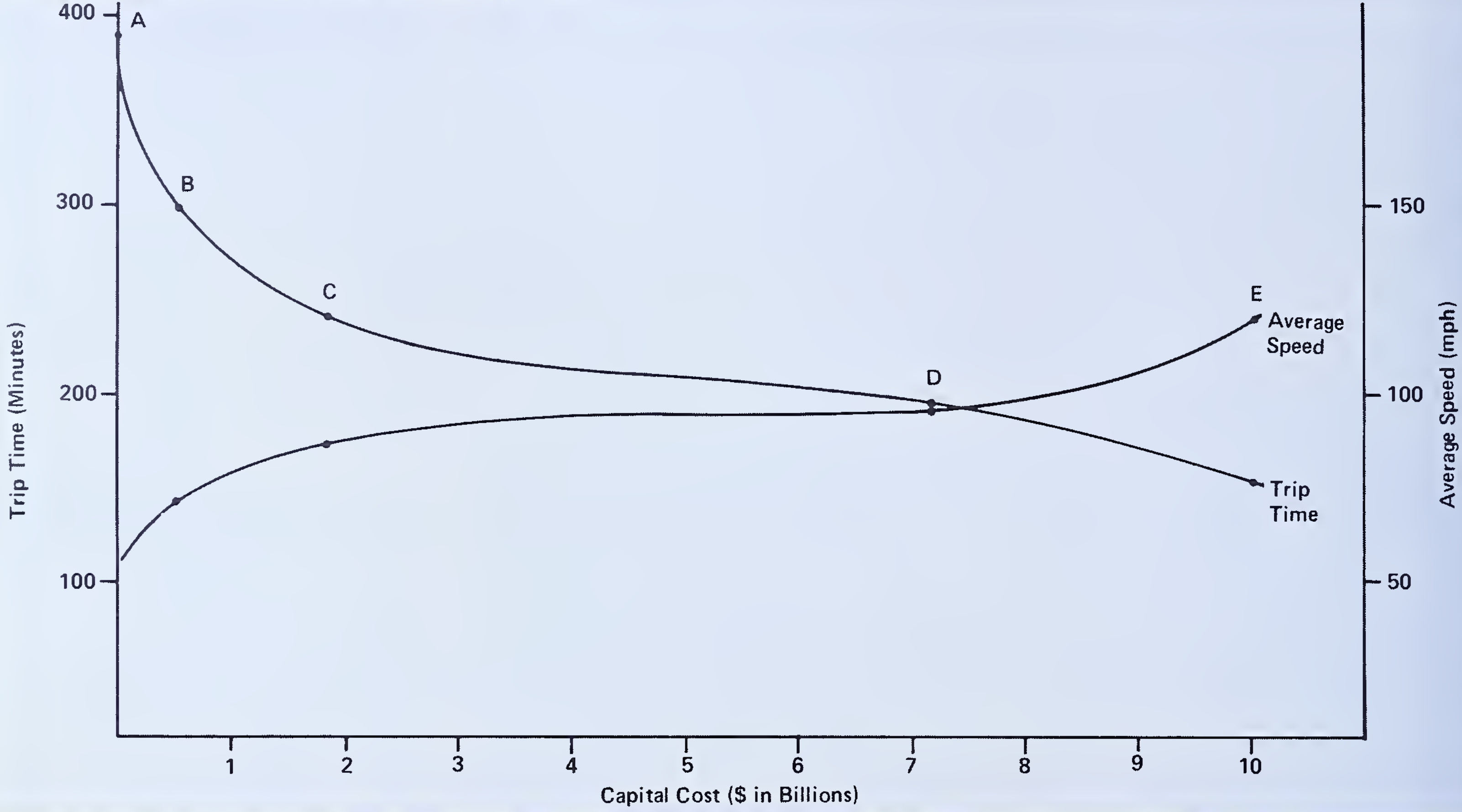
perhaps including elevated sections to allow agriculture on prime lands to continue uninterrupted. Historical sites near or within the rail system itself—such as Rockville Bridge, Horseshoe Curve, and certain stations, will require particular care.

Noise. Steel-wheel HSR trains are free from much of the noise of ordinary rail because of smoother track and electric propulsion. Maglev creates no wheel/track noise or vibration once it attains its lift-off speed. At high speed, all designs produce aerodynamic sounds that sometimes require noise control, as has been routinely provided in Japan wherever the Shinkansen traverses residential areas.

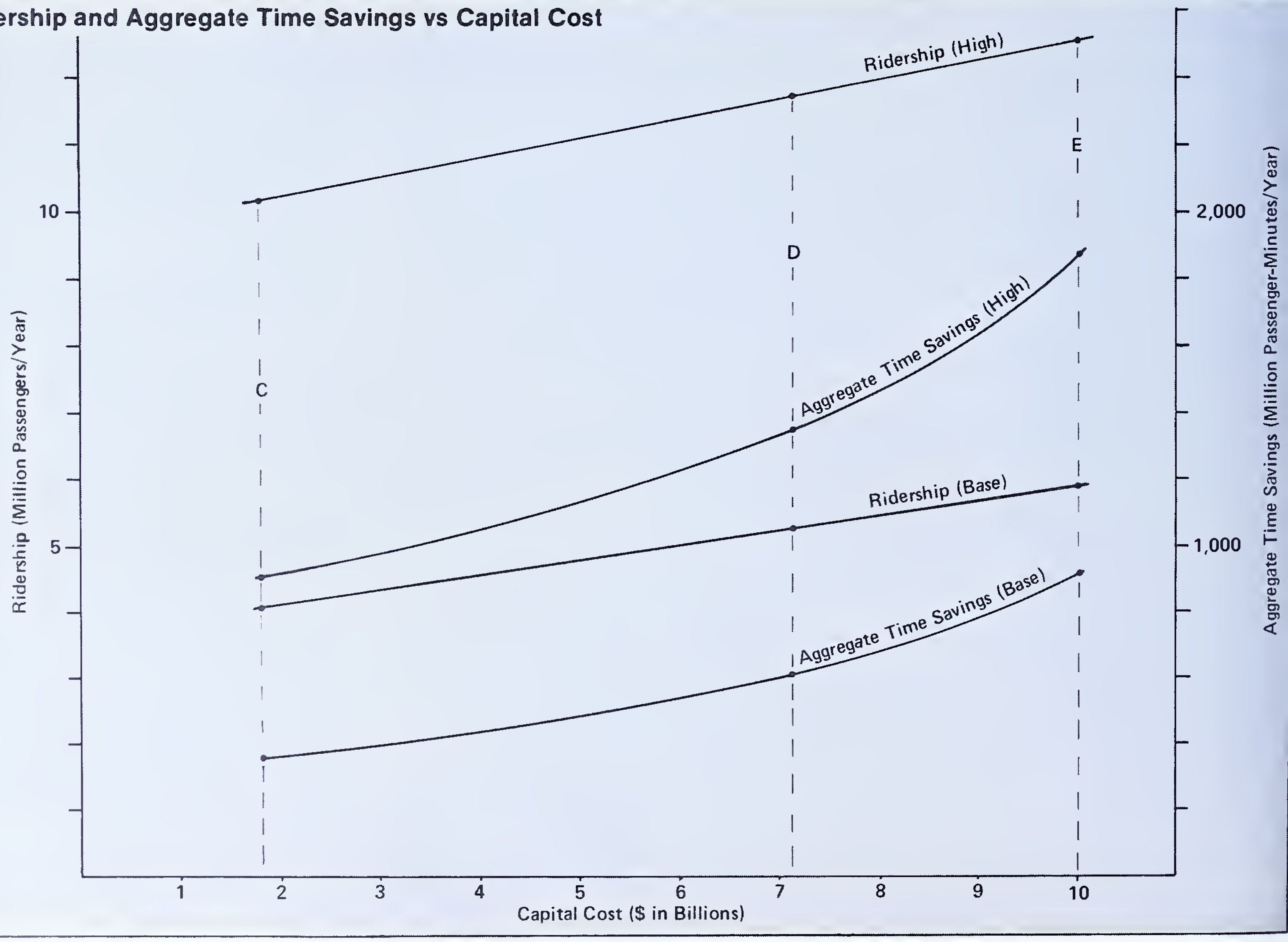
Health and Safety. The maglev alternative will need special study to determine whether magnetic fields pose any problems to riders or to people living nearby—if so, shielding can be provided. Both the German and Japanese test programs are investigating this issue. As for safety, well-maintained and -operated rail systems have excellent safety records (a tenth the fatality rate of automobiles), and Japan's Shinkansen shows that high speed rail can be astoundingly safe—20 years without a fatality or serious injury to passengers.

Environmental Program. While the environmental impact of any HSR alternative is not expected to be severe, Alternative C, which requires building only 50 miles of new route, would likely cause less environmental disruption than D (154 miles of new route) or E (238 miles). Any project stretching from one end of the state to the other will have substantial effects and will require early incorporation of mitigation measures into the project design. Similar problems at several sites can be handled collectively without expensive site-by-site solutions. In this process, all appropriate agencies and groups would be consulted. Developing a single programmatic environmental impact statement, supplemented by site studies as required, can simplify the gaining of environmental approvals, as compared to attempting numerous studies of individual

Average Speed and Trip Time vs Capital Cost



Ridership and Aggregate Time Savings vs Capital Cost



aspects of the system. Financing the project without federal support would mean that for the most part, only state agencies would have to approve the project, which could save approval time.

JAPAN AND FRANCE— TWO SUCCESS STORIES

Japan and France both run HSR lines at a profit. Both have extended their systems to new lines without any guarantee of achieving the financial successes of the first—France in pursuit of a public policy that insists on a vigorous passenger rail network, Japan as part of a decentralization policy to check the steady gravitation of population to a few main cities. Japan initiated its first line in the densely populated Tokyo-Osaka corridor (2,600 persons per square mile), where rail demand already exceeded the capacity of the existing system, but then extended it to much less densely populated corridors. France succeeded without such a dense population in the Paris-Lyon corridor (500 persons per square mile), and is now extending service to even less dense corridors.

The HSR concept has succeeded: the initial line of the Japanese system has operated profitably and fatality-free for more than 20 years. Pennsylvania can learn from these systems that success is possible, but must develop its own specific formula to achieve this goal.

ACTION

The fundamental questions raised at this stage of the study and for which guidance of the Commission is required to undertake the next phase are:

- Which technology should be given further study for potential application in Pennsylvania—the various steel-wheel high speed rail technologies, or magnetic levitation?
- If steel-wheel technology is selected for further study, should the focus be on essentially existing rail rights-of-way (Alternative C and C—Electric) or on a largely new right-of-way such as Alternative D?

Whatever decisions are made will affect the Commonwealth for many generations to come, as have previous choices such as the decision to build the Pennsylvania Turnpike—a real success story.

Alternative Evaluation Summary

	C	D	E
Name of Alternative	Improved existing	HSR	Maglev
Equipment type	Tilt body	Electric HSR	Maglev
Route Length (miles)	340.1	314.3	313
Miles of New Route	50	154	238
Percent at grade	90	73	67
Percent elevated	9	23	30
Percent tunnel	1	4	3
Trip time (hours:min)	3:58	3:16	2:36
Ridership (millions/year)			
Base Demand	4.18	5.15	5.87
High Demand	10.26	11.68	12.66
Capital Cost ($ in billions)			
Base Demand	1.84	7.17	10.0
High Demand	1.88	7.21	10.1
Internal Rate of Return (%) (Public Sector)			
Base Demand	4.7	1.0	0.5
High Demand	14.7	7.1	6.2
Employment Impact			
Construction Period (person-years)	18,000	75,000	97,000
Operating Period Jobs	8,300	9,600	12,500
Increase in Pa. Growth Rate (%)	23	27	35
State Tax Revenues ($ in millions)			
Construction Period, Total	95	385	490
Operating Period, Annual	13	15	19
Environmental Impact	Probably not significant	Significant but can be mitigated	Significant but can be mitigated
Implementation Risk	Lowest	Medium	Highest
Compatible (with potential through service)	Yes	Yes	No

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